A JOURNAL PUBLICATION

WATER WORKS & SEWERAGE

May, 1936 — Editor — Volume 83. No. 5

In LOS ANGELES . . .

at the A.W.W.A. CONVENTION

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California—a land apart from all others, like no other and distinctively itself—may be justly proud of her Los Angeles, well called the "Wonder City"—a metropolis sprung from desert sands out of ancient dreams, to sit as queen upon the shores of the sunset sea.

The metropolis of this Golden Empire, Los Angeles is the largest city in Western America. The population has increased from a scant 4,000 persons in 1860 to 1,294,600 inhabitants. The business district, with its ultra-modern shops and substantial edifices, presents a striking appearance. From the heart of this section you may view against the blue California sky the summits of Mt. Lowe and Mt. Wilson, where is located the world's largest reflecting telescope. Los Angeles harbor is now one of the great harbors of the world. Its growth has been phenomenal.

Five thousand miles of paved roads and streets radiate from Los Angeles, through palm-lined drives leading past unique homes built in the Spanish hacienda fashion, far-flung orange and walnut groves and forests of derricks in the oil fields.

Los Angeles extends a cordial invitation to the members of the American Water Works Association and affords the opportunity of seeing one of the greatest water works systems of the world, for a supplementary water supply, built at a cost of $25,000,000, is brought to the city, a distance of 233 miles from the snowy slopes of Mt. Whitney, the highest mountain in the United States. The capacity of the intake is 270,000,000 gallons per day.

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WATER WORKS & SEWERAGE

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L. H. ENSLOW, Editor

ARTICLES AND AUTHORS Scheduled for Future Issues

"Emptying Water Mains With Compressed Air"—Roger W. Esty and Nelson Boardman, Sup't and Ass't Sup't of the Danvers (Mass.) Water Department, will describe a very practical method of emptying water mains which was developed in Danvers and has proved effective in precluding or minimizing ditch pumping when cutting a line for repairs. This article is one of several to be contributed by water works operators during the year in a "Practical Operating Kink" series.

"Experiences With Anthrafilt at Denver"—open with a brief review of the value of crushed anthracite as a filtering material as used during a period of years at Denver. Then follows the more recent experiences, results, conclusions, concerning the effectiveness of a combination of anthracite and quartz sand in municipal filtration practice. The author, O. J. Ripple, long-time Superintendent of Filtration at Denver, presents the results of filtration experimentation, incident to the design of the new Denver Filtration Plant. His article was scheduled for this issue but, we regret, had to be held over.

"Comparative Costs of Iron Salts for Water, Sewage or Sludge Treatment"—Has been prepared by Wm. H. Baumgartner, Chemical Engr., Grasselli Chemical Co., at the specific request of "Water Works and Sewerage." His article will serve as a useful guide in the hands of engineers, chemists and others called upon to evaluate and make selections from the ferric-salts now available for treatment and sludge filtration. The analysis reveals their comparative efficacy as to coagulating values and their base cost in terms of available iron content. Included in the evaluation is the combination of ferrous-sulphate and chlorine to produce "chlorinated-copperas" at the point of usage.

"Centrifugal Dewatering of Sludges"—By Philip B. Streander, a Consulting Engineer of New York City, because of its thoroughness and length, proved too voluminous for a single issue. Part I, dealing with "Theory, Principles and Applications of Centrifugal Methods," appeared in our April issue. Part II, dealing with "Centrifugal Machines Now Available" (their design and characteristics) was scheduled for this issue. We regret that the length of the contribution and the arrangement of this issue prevented the scheduled appearance of Part II of Mr. Streander's article. Rather than depreciate the presentation by cutting the manuscript or leaving out illustrations, his article is being held for our June issue. The regrettable skipping of an issue is unavoidable.

"Scale and Corrosion Control in Aqueous Systems"—is being accomplished by modern methods, involving the use of organic-base inhibitors added to the water in closed systems such as are widely employed in industrial and manufacturing plant. D. W. Haering, Chemical Engineer of Chicago, with a broad experience in corrosion control, discusses this practice as it stands today. Industrial usage demands more than the treatment which municipal treatment provides and this topic is an important consideration in industrial water supply.

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色彩黝黑乃從木炭提煉而成如溶化之後其排除污濁之功效
較之普通木炭膠逾百倍至於使用方法僅須將炭素碰於桶內
桶上裝一半英寸口徑之啓閉門將該桶懸空而將開門下垂
救流歧加而合淺於沙濾池爲止倘或用乾式加藥機則此項爲
適宜
炭素和入之量準舊根據水質所含味足放份大抵每百萬加倫
水祇須耗用十二磅至二十四磅之炭素惟實際上究須視水中
所含氣味之若何程度而定如在混凝池內和入此活性炭素則
沉澄池底之泥漿不致發生厭化作用而濾池內之黃沙亦可藉
此得其滋潤並可減省氯氣耗量之利益
假或水料內容並無含有強烈氣味茲敢再介紹一種較有功效
之拉新科爭凝結品名曰黑磐(Black Aqua)此物係含有活
性炭素之吸凝作用與明礬之功效而成爲一種最經濟最易於
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按照最近統計大約在美國全境內有七百五十家以上之水廠
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自來水廠採用活性炭粉淨水 曩昔嘗有提議採用粒形活性碳晶，用以除去水中之異味雜色，終以此項手續須關一特別設計之濾水池及特製之拌和機械，對於設備方面，費用過鉅，頗不切合經濟而罷，近年以來關於製造活性炭方法，既日見改良，品質亦日趨進步，自 NUCHAR 粉質活性炭晶問世後，其使用方法無需特別濾水設備與機械作用，是吾人昔所認爲焦點而遲遲未能適用者，今則推陳出新，不復成爲疑義，現值美國境內自來水廠之採用活性炭粉，作爲日常淨水處理藥料已達八百家，即如我國上海英商自來水廠，杭州市自來水廠，天津自來水廠等家，近亦分別採用 NUCHAR 活性炭粉，驗其對於剷除水中之枯藻菌屑腥氣味，與消除氯氣及石碳酸藥味業已頗著成效云。

"Are you making your plans now to attend the National Meeting of the American Water Works Association, Los Angeles, Calif., June 8th to 12th? Many interesting papers are to be read and you should be present."

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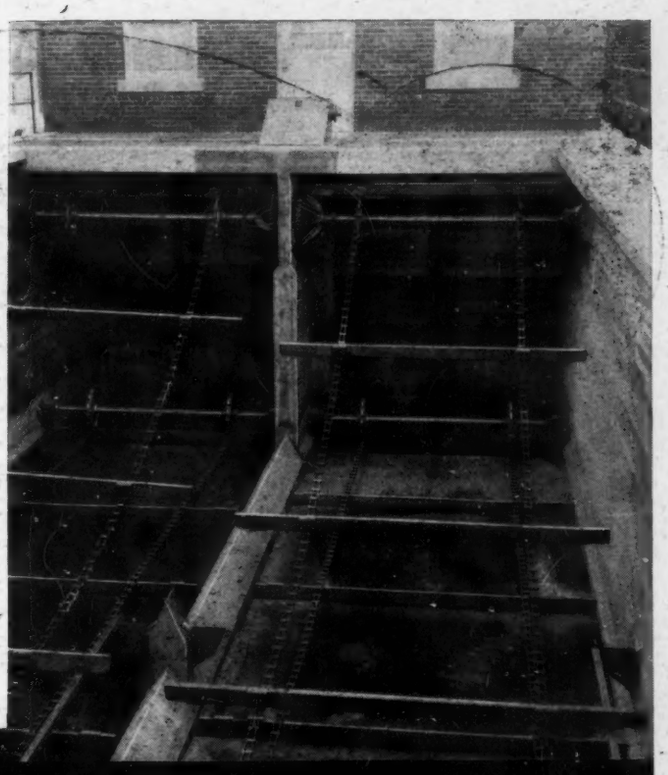

and the debris and suspended matter must be removed . . . .

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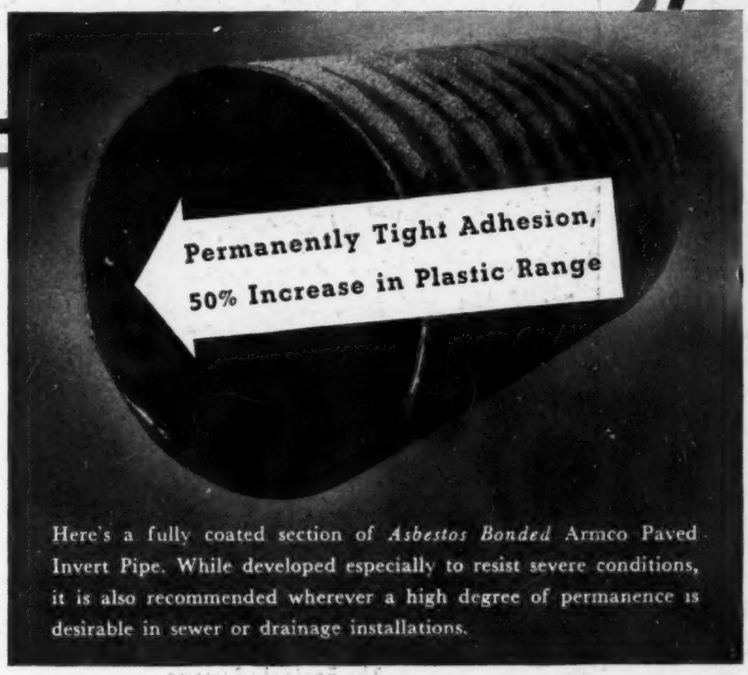

Here's a fully coated section of *Asbestos Bonded* Armco Paved Invert Pipe. While developed especially to resist severe conditions, it is also recommended wherever a high degree of permanence is desirable in sewer or drainage installations.

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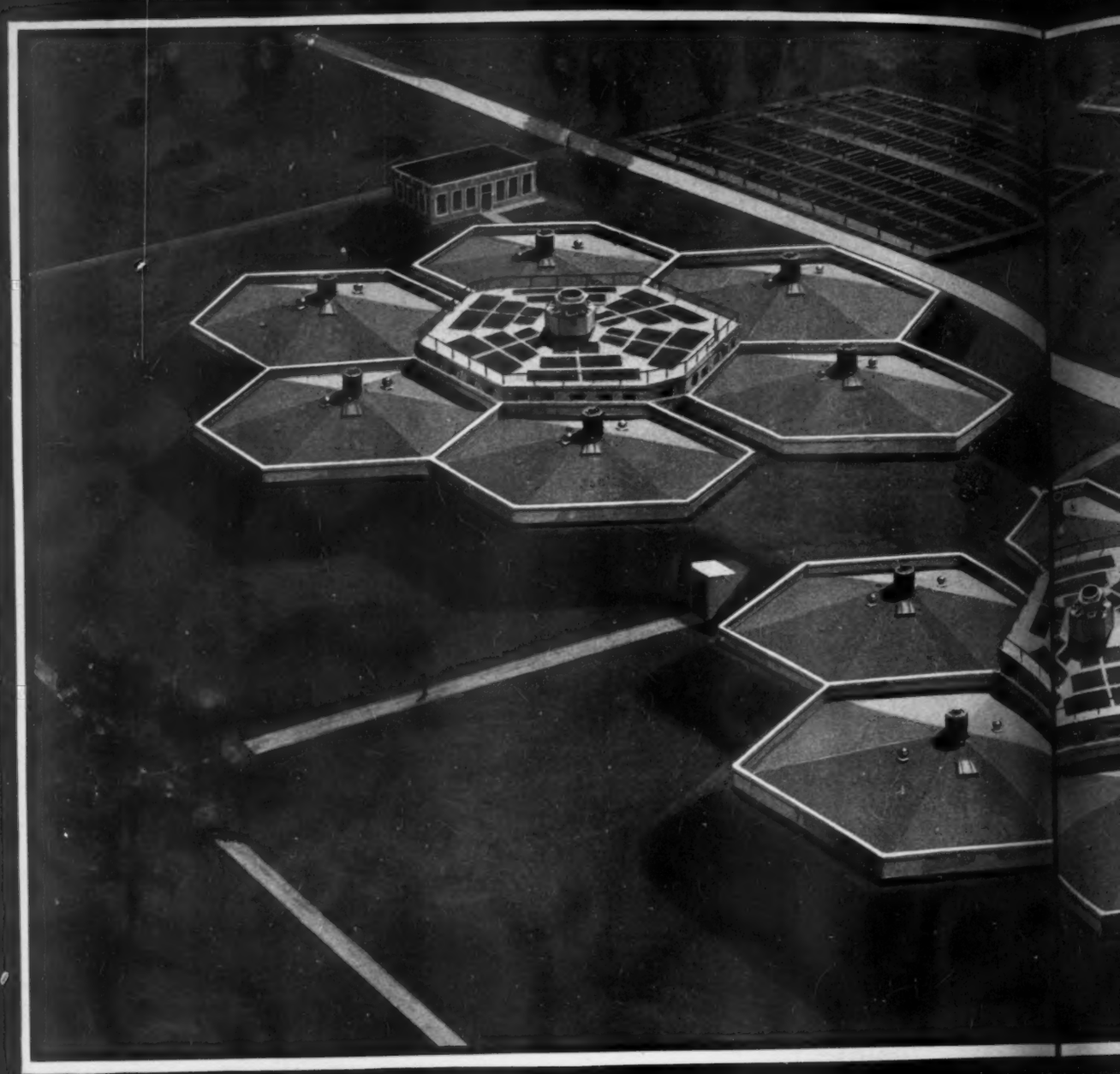

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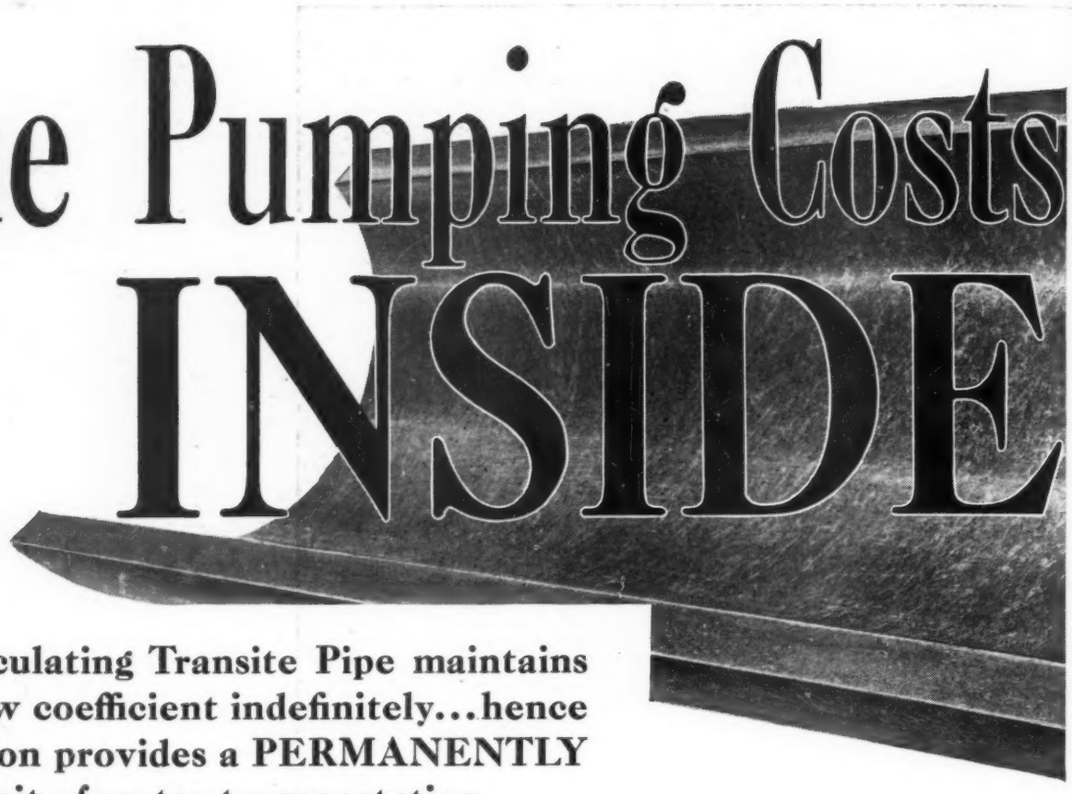

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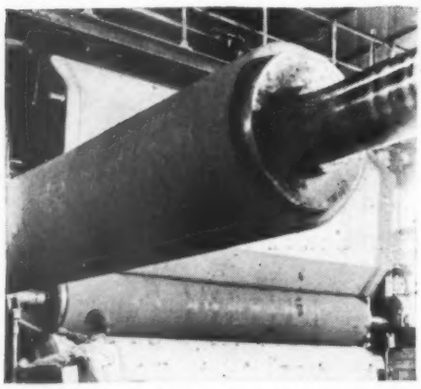
TRANSITE'S relatively light weight results in installation savings, too. As the picture shows, two men easily handled this 13-ft. length of 8" Transite. All sizes up to 18" can be handled without mechanical equipment.



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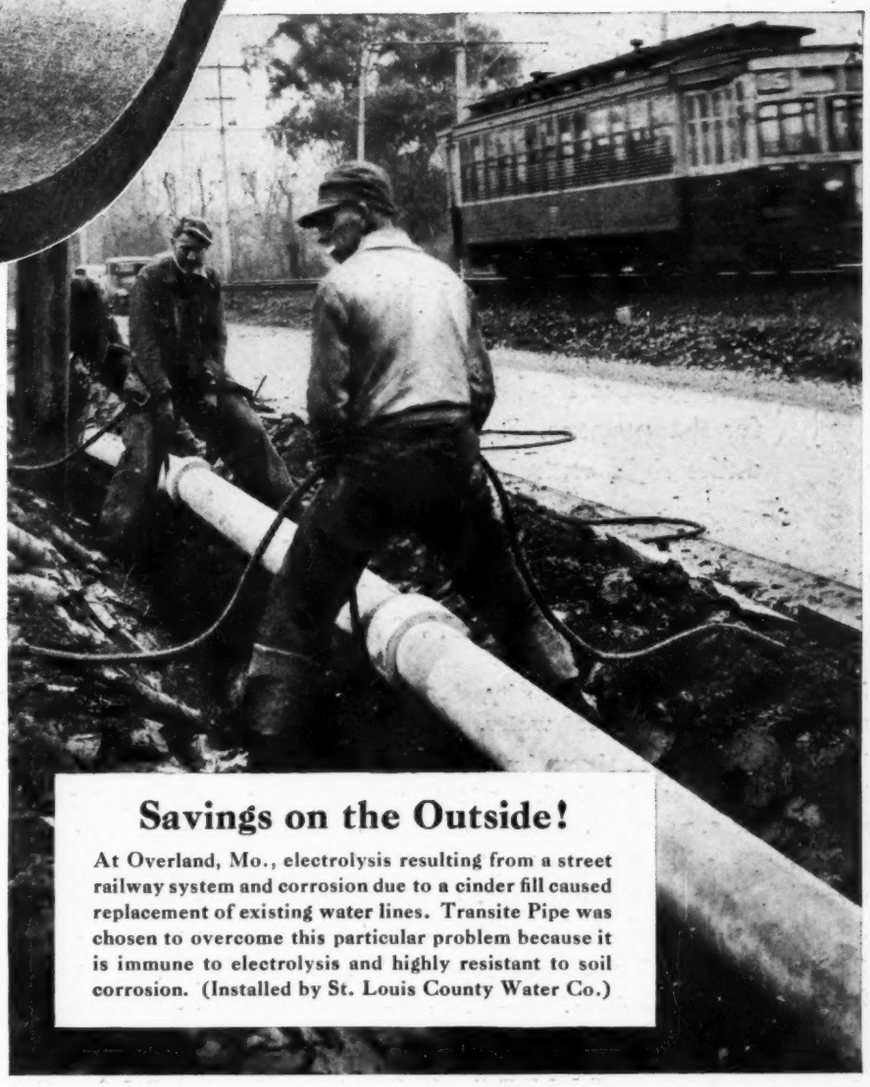
ON THIS TEXAS JOB, the flexibility of Transite's Simplex Coupling is well illustrated. The joints will remain permanently bottle-tight, eliminating a multitude of lesser leaks and preventing such leaks from causing breaks in mains by washing away supporting soil.



Savings on the Outside!

At Overland, Mo., electrolysis resulting from a street railway system and corrosion due to a cinder fill caused replacement of existing water lines. Transite Pipe was chosen to overcome this particular problem because it is immune to electrolysis and highly resistant to soil corrosion. (Installed by St. Louis County Water Co.)

TRANSITE PRESSURE PIPE

An ASBESTOS Product

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Municipalities faced with the elimination of objectionable taste and odors from their water supply are urged to consider CLIFFCHAR.

Produced in a plant devoted exclusively to wood chemicals and allied products, CLIFFCHAR constitutes an Activated Carbon of the highest order and characteristics.

It is produced solely from selected hardwoods—the most desirable of wood for the purpose. Every step of the process, from carbonizing to activating, is under rigid control.

CLIFFCHAR "R"

A SPECIAL GRADE FOR WATER PURIFICATION

In properties, size and density, CLIFFCHAR "R" is suited specifically to treat water.

Low phenol value, as shown by standard phenol tests, indicates its exceptional ability to remove phenolic and similar compounds.

Ground to extreme fineness (99% passing a 325 mesh screen) it gives maximum surface exposure with the greatest possible adsorptive capacity.

Controlled and uniform density accomplishes the dual features of assuring a suspension period long enough to take full advantage of its high adsorptive ability yet completely settle out in ordinary settling basins.

Finally, it will not cause "loss of head" when applied directly to sand filters.

The experience of water works officials in leading cities with CLIFFCHAR Activated Carbon is tangible evidence of its definite advantages.

We will be glad to furnish further information or report on any specific question. Your inquiry involves no obligation.

CLIFFS DOW CHEMICAL COMPANY
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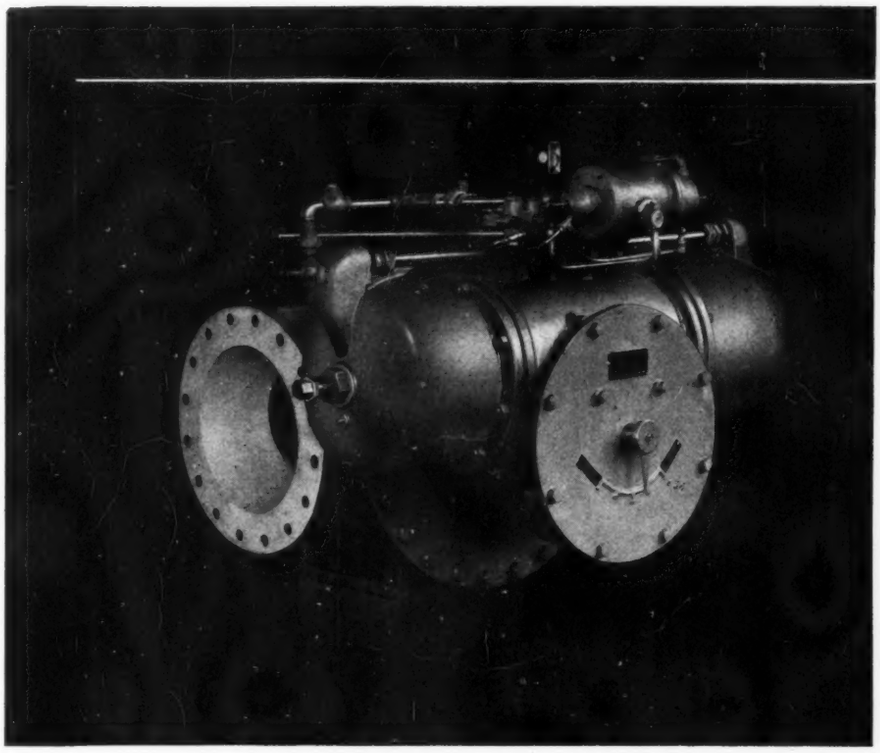

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Compact, neat — Monel metal seat rings — 3-bearing mounting of plug — full Alemite lubrication — all working parts can be removed with pressure on valve — can be installed in any position — are designed to accommodate any type of automatic control.

See our Exhibit at A. W. W. A. Convention in June, at Los Angeles, Calif.

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THE OLD WAY and the NEW
SHOWING
the relative space required for drying sludge on sand filter beds in a city of 100,000 population, contrasted with that occupied by the Nichols Herreshoff Incinerator to assure *complete* disposal. The sludge bed area is approximately 100,000 sq. ft. and the incinerator area about 2,500 sq. ft. . . . . in the ratio of 40 to 1.

NO better evidence shows the compactness of a Nichols Herreshoff Sewage Sludge Incinerator installation than the comparative illustrations herewith. They graphically visualize the economy of space made possible by this improved, scientific way to dispose of sewage sludge solids by *burning*. The resulting residue is a dry, odorless, virtually inorganic ash. Minimum labor and maintenance costs also assure maximum economy of operation.

Engineers and public officials interested in solving municipal waste disposal problems by this economical, sanitary method are invited to send for more complete details.

NICHOLS HERRESHOFF
SEWAGE SLUDGE
INCINERATOR

NICHOLS ENGINEERING & RESEARCH CORP.
40 WALL STREET, NEW YORK

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3100 NINETEENTH STREET, SAN FRANCISCO

WPA project No. 2236, Fresno, California; Jean Vincenz, Director of Public Works. One mile of 30-in. reinforced concrete sewer pipe connects airport to 48-in. concrete outfall built in 1917. Maximum cut on new project, 12 ft.

FRESNO LOOKED AT PAST PERFORMANCE AND CHOSE *Concrete Pipe* FOR ITS NEWEST SEWER PROJECT

FRESNO'S WPA project begun early in 1936 calls for one mile of 30-inch concrete pipe running from the airport to a 48-inch concrete pipe outfall sewer built in 1917.

Concrete pipe was selected because of the excellent service record of this older sewer, which was built with 5-inch walls and runs one-half to two-thirds full except under rare storm conditions, with 2½ feet per second average velocities. The old pipe was found to be in perfect condition after 19 years of service.

Fresno has nearly 25 miles of concrete pipe sewers, all in first class condition.

Satisfactory sewer performance requires good materials plus proper design, construction and operation. That means the use of concrete, and the supervision of an experienced sanitary engineer. His service is cheap insurance on the success of these important jobs.

Write for booklets "*Monolithic Concrete Sewers*" and "*Concrete Pipe Sewers*," providing helpful data on the use of concrete in sewers. Free upon request.

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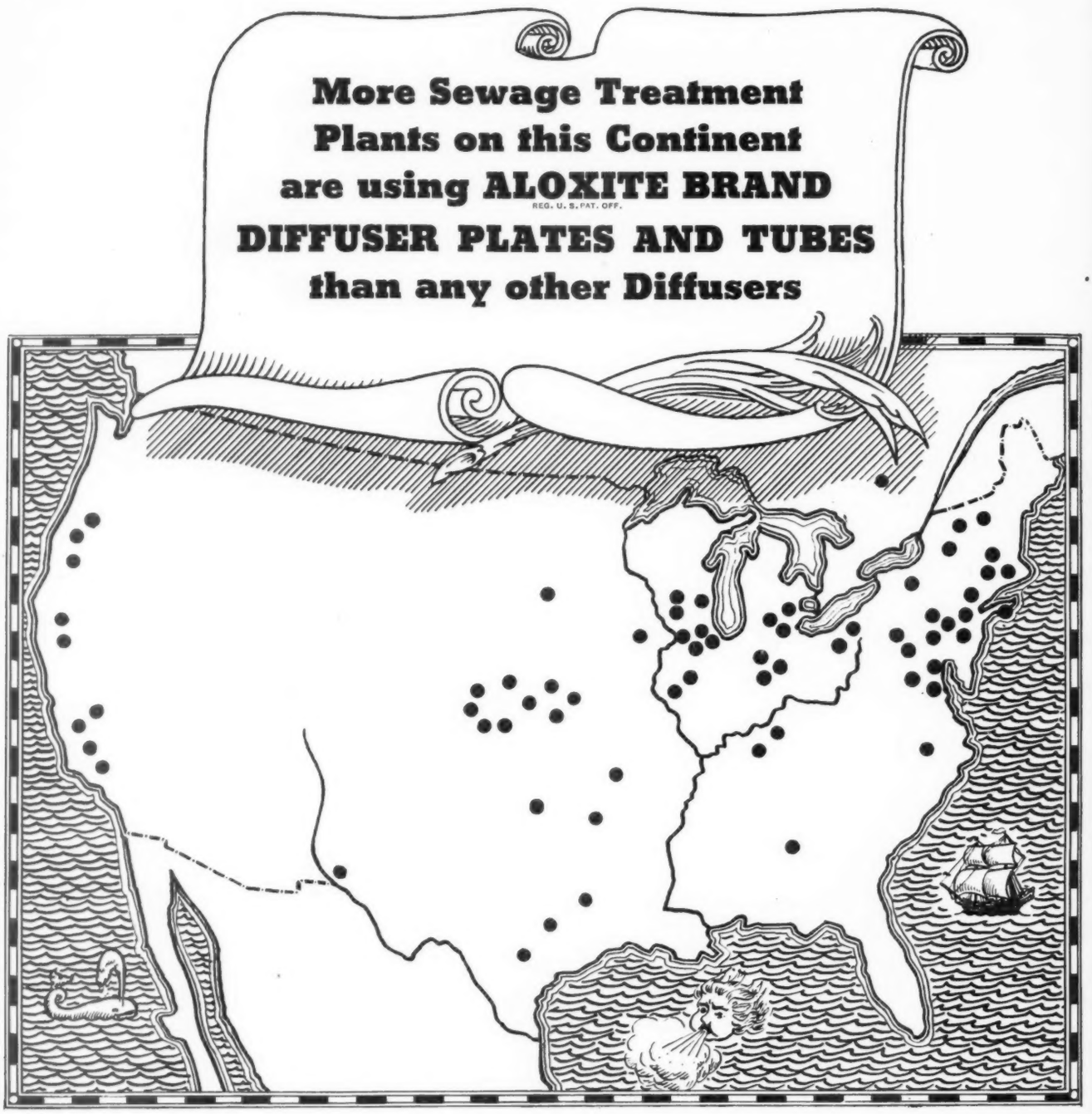
Dept. A5-29, 33 W. Grand Avenue, Chicago, Ill.


More Sewage Treatment
Plants on this Continent
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REG. U. S. PAT. OFF.
DIFFUSER PLATES AND TUBES
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It means that skilled research and experienced engineering service have combined in the production and application of these products of superior quality and proved characteristics.

Write our Sanitary and Filtration Department for information on design, specifications and engineering data on the application of these diffuser mediums in sewage and water plants.

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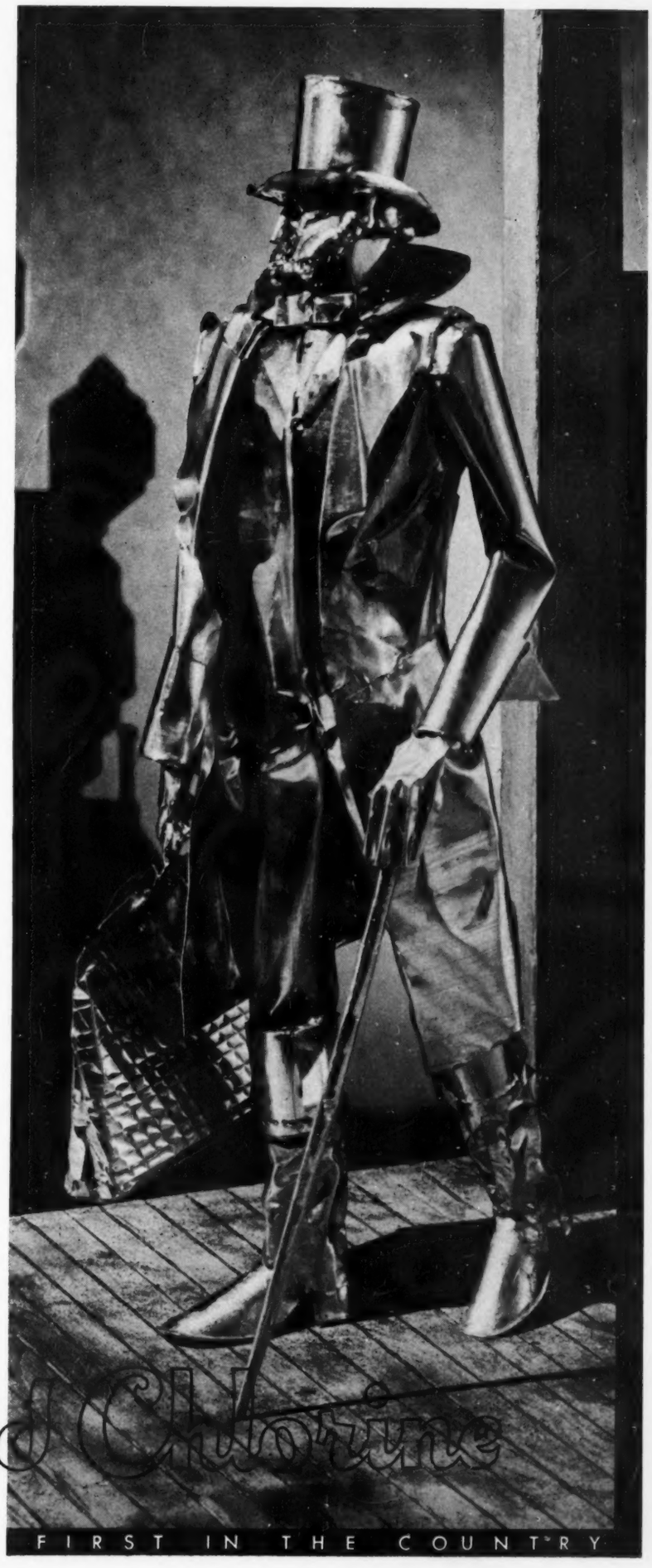
BY L. L. BALCOM



TO the pioneer railroad builders of the last century goes the credit for opening up rich, new territories in the West. To the pioneer chemical companies of today goes the credit for opening up many rich, new fields of activity for industry. Among these companies is EBG—first to produce Liquid Chlorine in the U. S. A. New frontiers... new pioneers! Yet the old confident spirit of the empire builders lives on. When you need Liquid Chlorine—or experienced counsel regarding its use—turn to EBG, the pioneer—first in the country!

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EBG Liquid Chlorine

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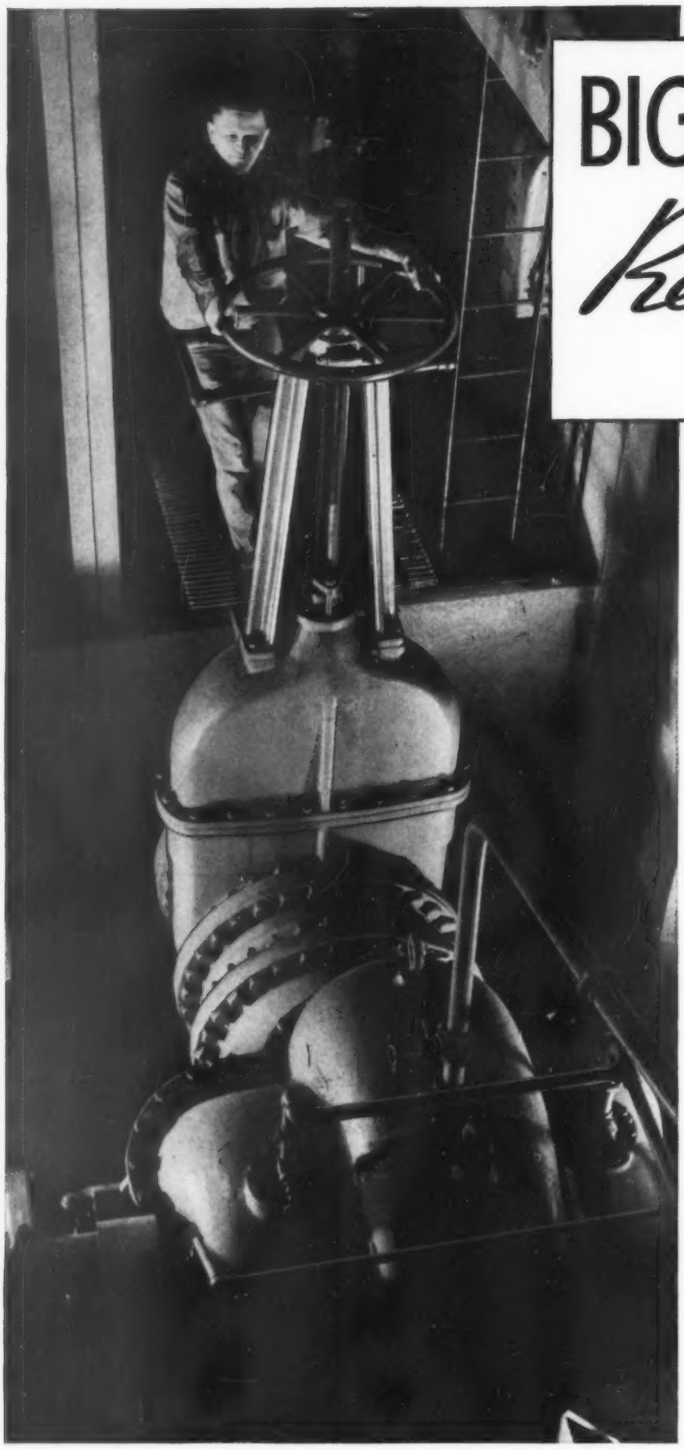

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● Men who must shoulder the responsibility of specifying extra large valves dare not guess, seldom can risk experiment. Investments are too large, demands for reliability too imperative.

To their aid Crane brings an abundance of experience and a fund of engineering knowledge built up over three-quarters of a century. Coupled with the outstanding design features of Crane's large valves is a perfected manufacturing technique and the kind of craftsmanship that makes results positive.

Where time is important, the great range of sizes, types, pressure groups and operating mechanisms which Crane is prepared to supply are a decided advantage.

The Crane branch or distributor near you is prepared to give you valuable cooperation and complete information on stock as well as special designs.

When you attend the A. W. W. A. Convention at the Los Angeles Biltmore, June 8 to 12 don't miss the Crane exhibit on display there.

● *Crane 36-inch, O. S. & Y. low-pressure gate valve on centrifugal water pump. Disc accurately guided to its seat, minimizing wear of faces. May be fitted with spur or bevel gearing, or with cylinder for hydraulic operation or with motor drive.*

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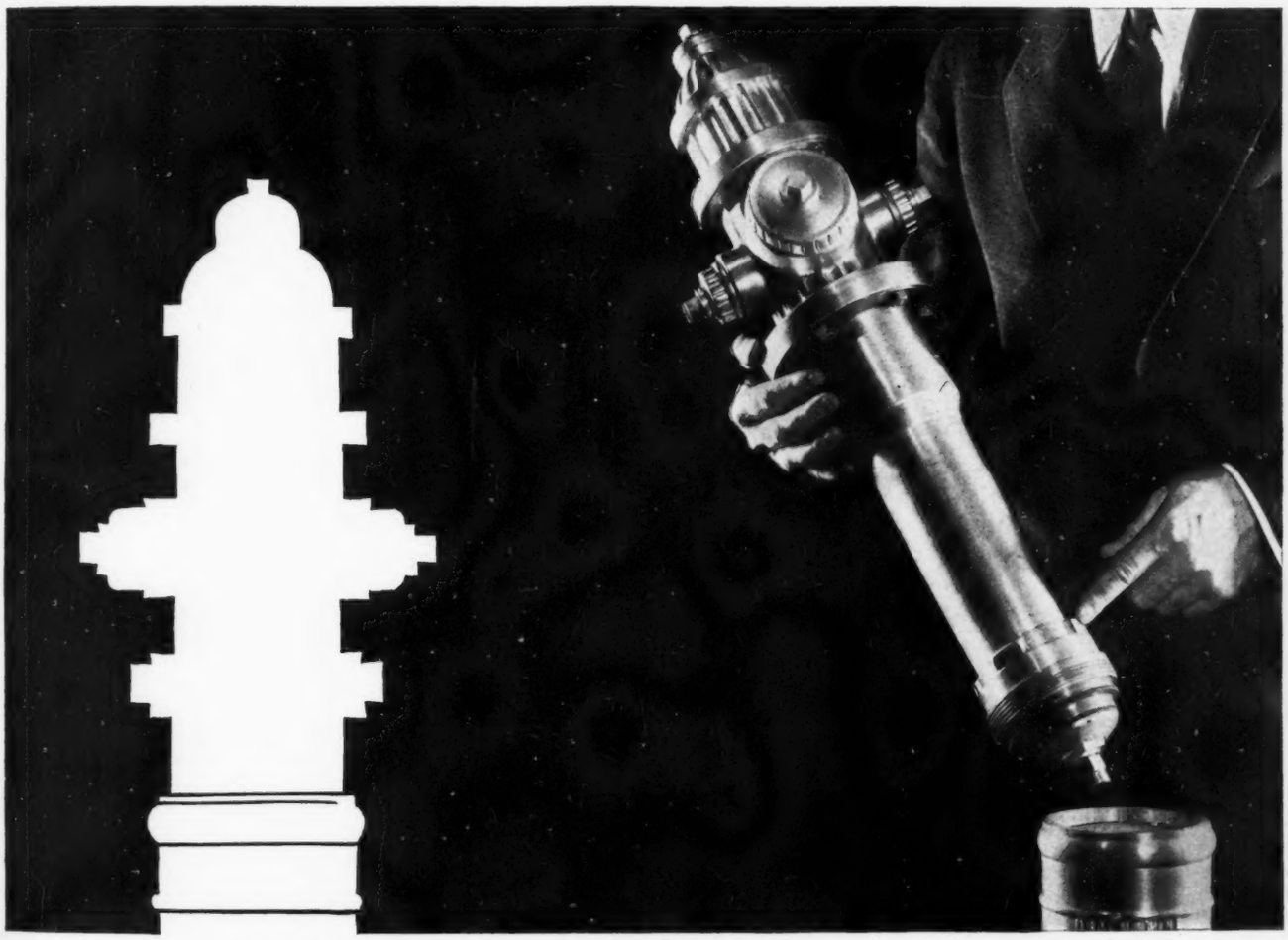
This barrel contains all working parts. It is interchangeable with every Mathews Hydrant ever made of the same diameter and trench depth. It is inserted without digging a spoonful of earth or breaking an inch of pavement. Whether Mathews Hydrants are 60 years old and in need of modernizing or 6 months old and broken by traffic, you can renew them in 15 minutes and save excessive installation costs.



See pages 124 and 125 of this issue

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"We were one of the first to recognize the advantages of HTH"

G. H. Sargent, City Engineer at LaGrange, Georgia, where HTH is used at the filtration plant, in wells and at swimming pools, including the new municipal pool and the local country club pool.

FEW finer tributes have been paid to the usefulness of HTH than that of G. H. Sargent, City Engineer of the City of LaGrange, Georgia. "When you brought out HTH a few years ago, we were one of the first to recognize its advantages as a quick and convenient source of chlorine," writes Mr. Sargent. "We have used it successfully at the filtration plant at times to overcome a CO_2 condition in the raw water supply, adding a solution of HTH with the alum."

"We have also recommended HTH for use in wells and in swimming pools including our local country club pool where it is used in the pool water and for locker room sanitation. The use of HTH in our municipal swimming pool, opened in the spring of 1935, in locker room foot baths and for scrubbing all floors, is responsible in our opinion for the absence of a single case of athlete's foot around the pool."

LaGrange offers still another instance where Mathieson Chlorine and HTH work hand in hand for better sanitation. "We have used your Liquid Chlorine practically ever since our filtration plant was built, twenty-one years ago," says Mr. Sargent. "In that time we have never had a complaint due to sticking valves or lack of proper service."

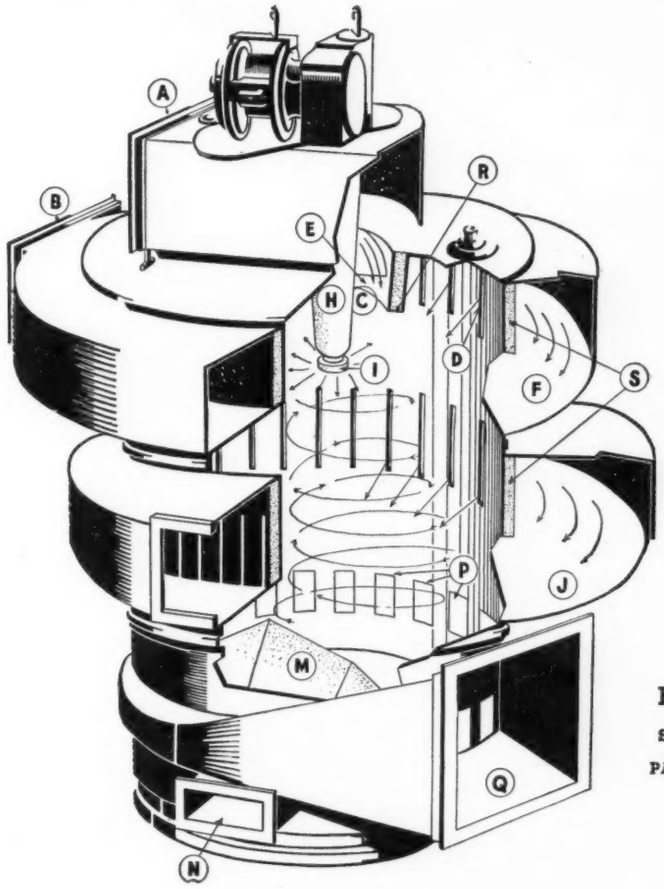
Filtration Plant, City of LaGrange, Georgia. Since this plant was built twenty-one years ago, Mathieson Liquid Chlorine has been used regularly.

The MATHIESON ALKALI WORKS (Inc.)

60 East 42nd Street **New York, N. Y.**

Soda Ash . . . Liquid Chlorine . . . Bicarbonate of Soda . . . HTH and HTH-15 . . . Caustic Soda . . . Bleaching Powder . . . Ammonia, Anhydrous and Aqua . . . PH-Plus (Fused Alkali) . . . Solid Carbon Dioxide

New UNIT Spray Drying and REACTION CHAMBERS



SIZES 5 and 10

For detailed explanation send for Bulletin No. 3

PATENT ALLOWED AND PENDING

BOWEN RESEARCH CORPORATION

GARWOOD, NEW JERSEY

Announcing....
A BLESSED EVENT

...in the
WATER WORKS FIELD

● The new baby's initials are A. A. C.

● This newcomer has big things ahead. Soon—very soon, we hope—it will be offering you valuable aid, developed through extensive research in the field of coagulation and taste and odor control.

HERE'S THE BABY'S CARRIAGE

● Never saw one like this before, did you? Pulled, instead of pushed! A completely outfitted water works laboratory on wheels ● Includes apparatus of special design, which will determine the influence of varying coagulants upon different potable waters.

The PRODUCTS: ● BLACK ALUM—an activated carbon-compounded coagulant. Produces fast floc formation and better defined floc. Stabilizes sludge—conditions filter sand. ● COAG—a new coagulant containing activated carbon and other coagulating compounds. Developed especially for fields which require a highly efficient coagulant at a cost below that of regular Alum.

● Both in limited production, east of the Mississippi only—for the present.

● Samples? Yes, we'll be glad to send them, along with more specific information. Address:

"THE HOUSE OF COAGULATION"

Activated Alum Corp.
Main Sales Office:
80 BROAD STREET NEW YORK CITY, N. Y.

HE *was* ON THE SPOT

But he bounced off. Here's the story: Breaks had started in the sewer line. Bad odors all over town. The sewer bonds not yet half retired. . . . The voters blamed the city administration. Election time drew near . . .

Then the Mayor happened to read an article on "Use of Chemicals in Sewage Treatment". It explained that Hydrogen Sulphide (H_2S)—generated in the sewage by bacteria—causes bad odors, forms sulphuric acid, which destroys sewer lines long before their time. The article stated further that BEAR BRAND CHLORINE, applied to sewage, prevents formation of H_2S, neutralizes it if already present, stops odor nuisance, protects sewer lines against untimely destruction.

Of course, the Mayor decreed that the sewage be treated with Bear Brand Chlorine. He was reelected.

In many California communities mayors, supervisors, councilmen, may find themselves on the same spot. It's so easy to avoid it. Installation cost of chlorination equipment, and upkeep, are low. You may have a reprint of the "Use of Chemicals in Sewage Treatment" for the asking. Also detailed information on chlorination. Let us know your plant capacity and method of treatment.

Liquid Chlorine • Ammonia • Ferric Chloride

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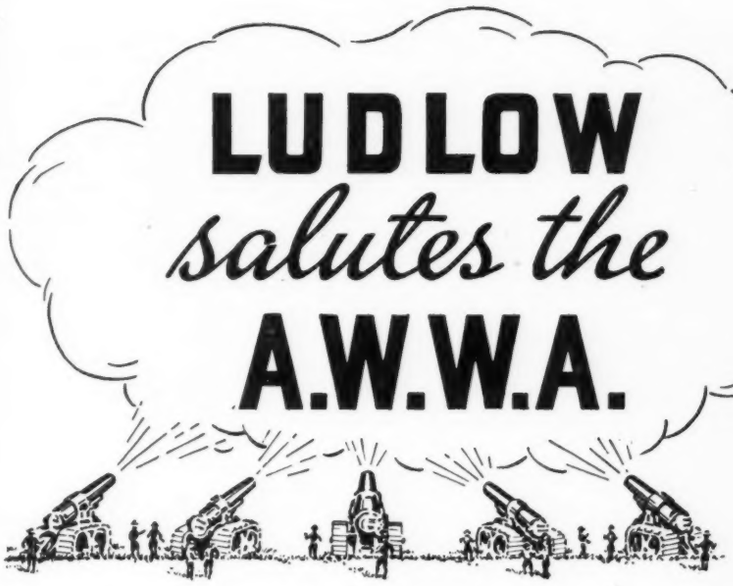
GREAT WESTERN ELECTRO-CHEMICAL CO. BEAR BRAND PRODUCTS SAN FRANCISCO, CALIF.

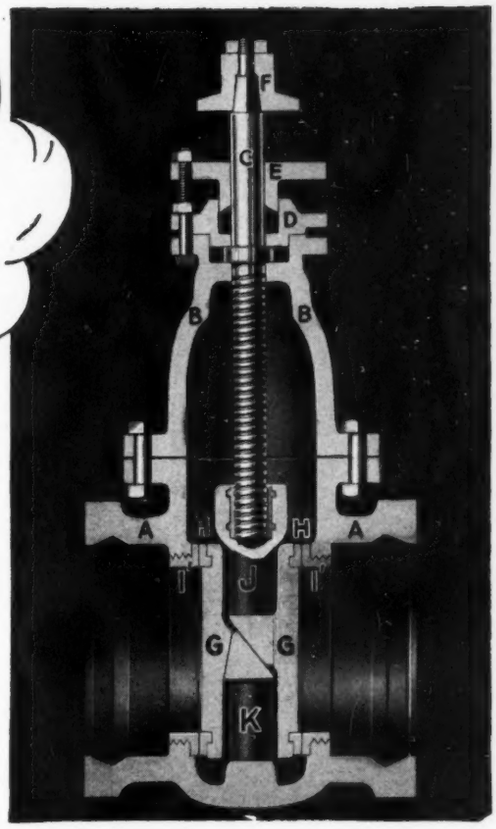
LUDLOW *salutes the* A.W.W.A.



When the American Water Works Association held its first annual council meeting 56 years ago The Ludlow Valve Mfg. Company was already 14 years old.

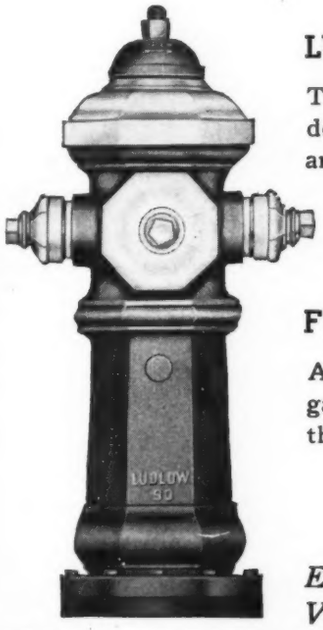
Ludlow made its first great contribution toward reliable and efficient water works equipment as originator of the double disc gate valve. Each year since, has seen other contributions —refinements in valve and hydrant design—the development of better materials—greater precision in manufacture—improved service to the industry.

Ludlow salutes the A.W.W.A., and is proud of its record of cooperation with and service to the leading water works engineers of the country.



LUDLOW GATE VALVES

The original Ludlow design is still the standard on which all double disc gate valves are patterned. Look at this cross section—its simplicity—ruggedness — unusually small number of working parts. There are Ludlow valves over 50 years old in active service. Ludlow valves are available in every size and style used by the water works industry.



LUDLOW NO. 90 HYDRANT

This hydrant combines to an unusual degree, efficiency, graceful design, and simplicity of repair.

SEWERAGE AND FILTRATION EQUIPMENT

All types and sizes of valves, shear gates and sluice gates are included in the Ludlow line.

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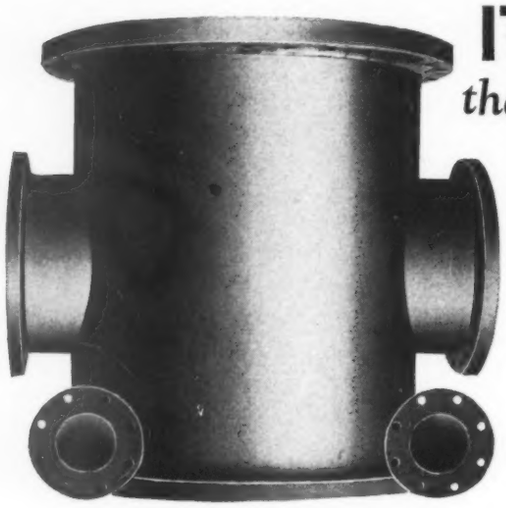
Every Ludlow Water Works Valve is built to specifications of the American Water Works Association. Send for a complete Ludlow catalog.

The LUDLOW VALVE MFG. CO. TROY NEW YORK

LFC



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"LYNCHBURG" has built its enviable reputation on its ability to produce difficult "SPECIAL" fittings and big cast iron pipe of the finest quality—work that demands the best Foundry Technique . . . Special equipment, and an organization trained to the job enable us to boast that a job does not come too large or difficult for us to handle with dispatch . . . Write, Wire or Phone "Lynchburg" for quick estimates.

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Cast Iron Flanged Fittings and Flanges. From 1" to 84".
Super-de Lavaud Centrifugal Cast Iron Pipe.

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STEEL GRATING
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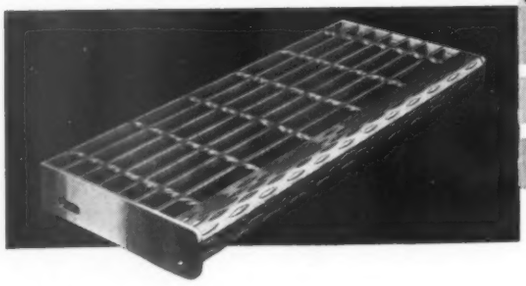

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SELF-CLEANING
NO RATTLES • EASILY PAINTED

See and examine this one-piece, non-slip grating for yourself. We have prepared a sample, paper weight size, and will be glad to send it to you on request together with complete catalog. Just say—send Grating sample.

Blaw-Knox Steel Stair Treads are made from Electroforged steel grating using a nosing made from rolled diamond checkered plate which sharply defines the edge of each tread. Available in all standard sizes. Ask for Form 1498.

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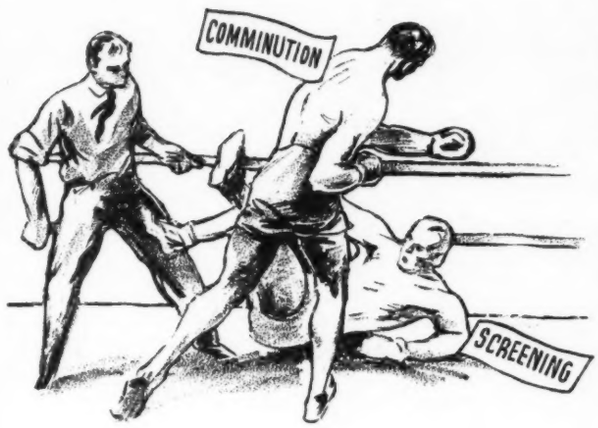

COMMINUTION *knocks out* SCREENING

● No Screenings to handle where coarse material in raw sewage is comminuted. The cut-up material settles rapidly in the Primary Tank and is pumped without trouble to the Digestion Tank for final disposal.

Fig. 1970 — 15" Comminutor. This machine eliminates Bar Screens and the handling of screenings by cutting up coarse material in raw sewage without removal from the channel.

COMMINUTOR ELIMINATES BAR SCREEN

● The Comminutor is installed in the raw sewage channel either indoors or outdoors with its revolving slotted drum partially submerged. Raw sewage flows through the slots in the side of the drum, out its bottom, and on to the Primary Settling Tank. Stellited cutters on the drum comminute coarse material to pieces small enough to pass through the ¼" or ⅜" slots.

COMPETENT ENGINEERING SERVICE TO CONSULTANTS.

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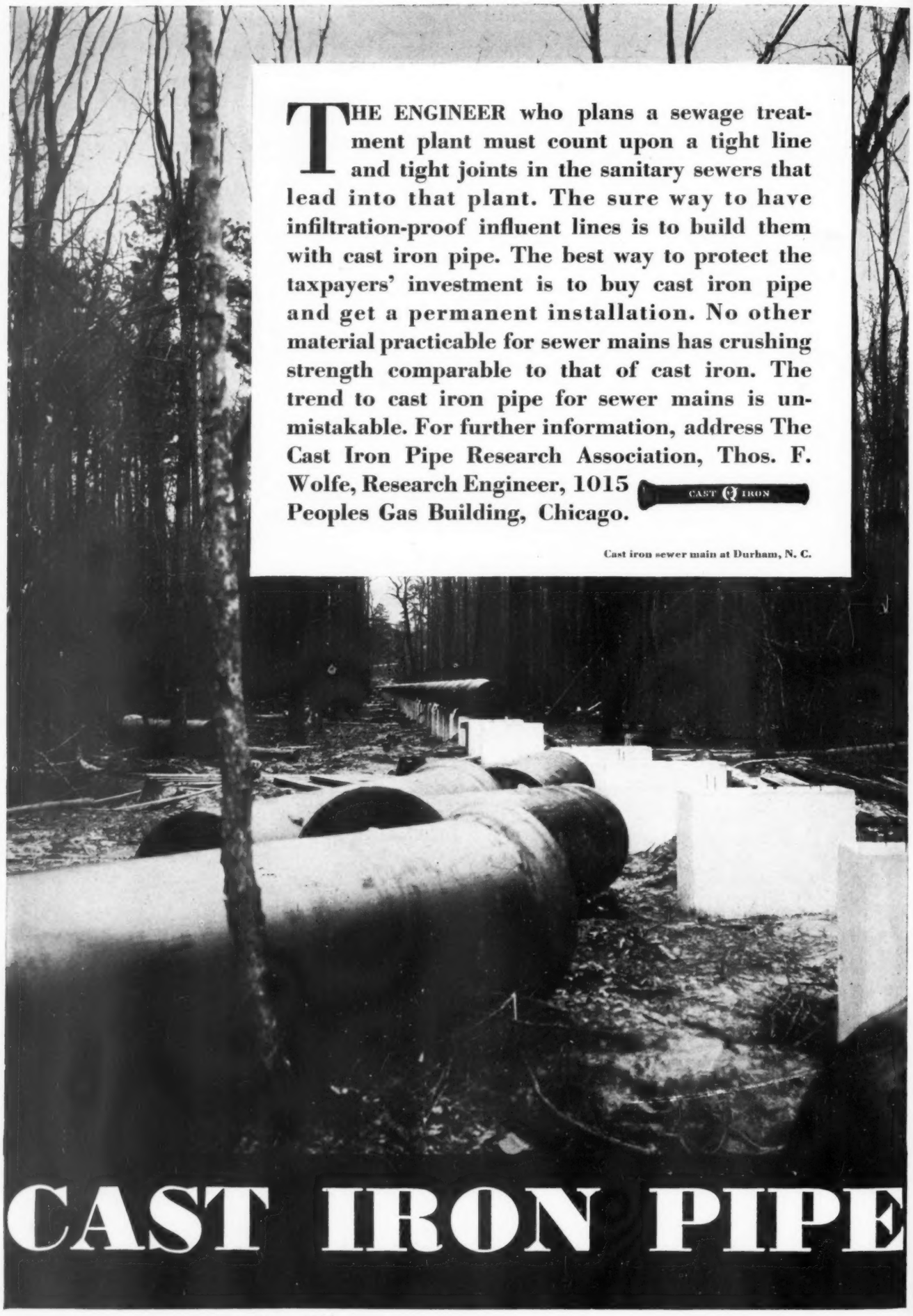


THE ENGINEER who plans a sewage treatment plant must count upon a tight line and tight joints in the sanitary sewers that lead into that plant. The sure way to have infiltration-proof influent lines is to build them with cast iron pipe. The best way to protect the taxpayers' investment is to buy cast iron pipe and get a permanent installation. No other material practicable for sewer mains has crushing strength comparable to that of cast iron. The trend to cast iron pipe for sewer mains is unmistakable. For further information, address The Cast Iron Pipe Research Association, Thos. F. Wolfe, Research Engineer, 1015 Peoples Gas Building, Chicago.

CAST IRON

Cast iron sewer main at Durham, N. C.

CAST IRON PIPE

WATER WORKS AND SEWERAGE
A GILLETTE PUBLICATION
VOL. 83 MAY, 1936 No. 5

A NOVEL GRAVITY FILTER PLANT

By W. MARTIN JOHNSON, C.E.*

Lynchburg, Va.

The Author

THE historic Town of Lexington, Virginia, is located in a section of the state which has always attracted many tourists, who come to visit its many points of historic interest and natural beauty throughout the year. It is the home of the Virginia Military Institute and of Washington and Lee University, two of Virginia's oldest and most cherished institutions of learning. Its water supply, which serves the industrial and domestic needs of the community, as well as the needs of the two institutions, is publicly owned and generous provisions have been made and are being supplemented to provide a safe and attractive water supply service for the use of the community and its many visitors and guests.

The primary water supply has been obtained from springs and mountain streams, which flow by gravity with abundant head into the distribution reservoir of two million gallons' capacity, which is cut into the top of a dome shaped hill on the outskirts of the town. As the town and its requirements have increased, the available gravity supplies have failed to meet the demands during certain seasons, and it has from time to time become necessary to provide emergency pumping stations to temporarily supplement the supply from various close-by springs, which, in turn, have not been found adequate to give permanent relief.

With the assistance of the PWA the town has now been able to meet a long felt need for the development of a permanent and adequate emergency supply to supplement its splendid gravity system. The gravity supply which is of exceptional quality and purity is at present untreated, except for chlorination, while the auxiliary supply, which is to be obtained from the Maury River, previously known as North River, will require complete treatment. As the mountain supply, however, becomes more or less turbid at certain seasons of the year, it was, of course, found desirable to locate the new treatment plant at a point, where both the gravity and the supplementary river supplies could be treated, and the site of the present distribution reservoir offered the only logical point for the location of such a plant.

Selecting Location and Design of Plant

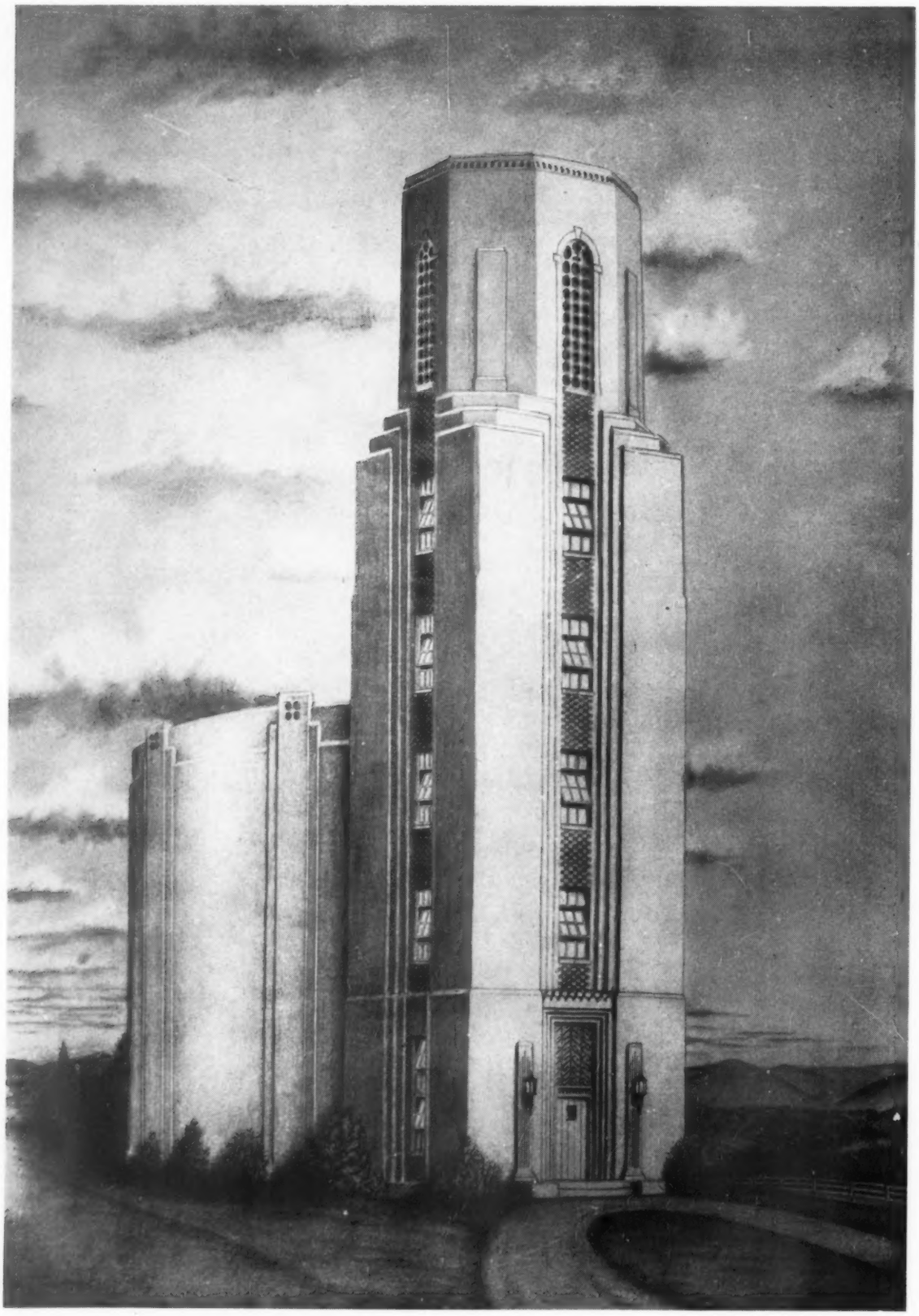
The distribution reservoir is located at just sufficient elevation to deliver the water to the various sections of the community. Due to the topography of this site, and the absence of elevated ground for the location of the treatment plant in that vicinity, it was impossible to use a conventional type of filter plant and also avoid the necessity of pumping the filtered water from one or the other source to the reservoir. This, notwithstanding the abundant head available on the existing mountain gravity system, unless pressure filters were used, which was not considered desirable. After a study of this situation, it was decided that the electric power requirements and standby charges could be greatly reduced by the development of an elevated (multi-story) type of filter plant to eliminate pumping costs for the greater part of the time during which the gravity supply will be entirely sufficient. Furthermore, the savings in standby charges during periods when filtration of the gravity supply is not required was an added consideration.

The rather unusual filter plant design of 800,000 g.p.d. capacity was developed to meet these special conditions. As shown by the accompanying photograph and plans, the plant consists principally of a vertical cylindrical reinforced concrete sedimentation tank 39 feet in diameter by 40 feet high, with reinforced concrete filter tanks and chemical mixing chambers, built into the top of the coagulation tank, and at such elevations as to obtain gravity discharge of the plant effluent into the present distribution reservoir which occupies the top of the hill. The maximum water level of this reservoir is 14 feet above the base of the filter plant structure when located on the highest available adjacent ground.

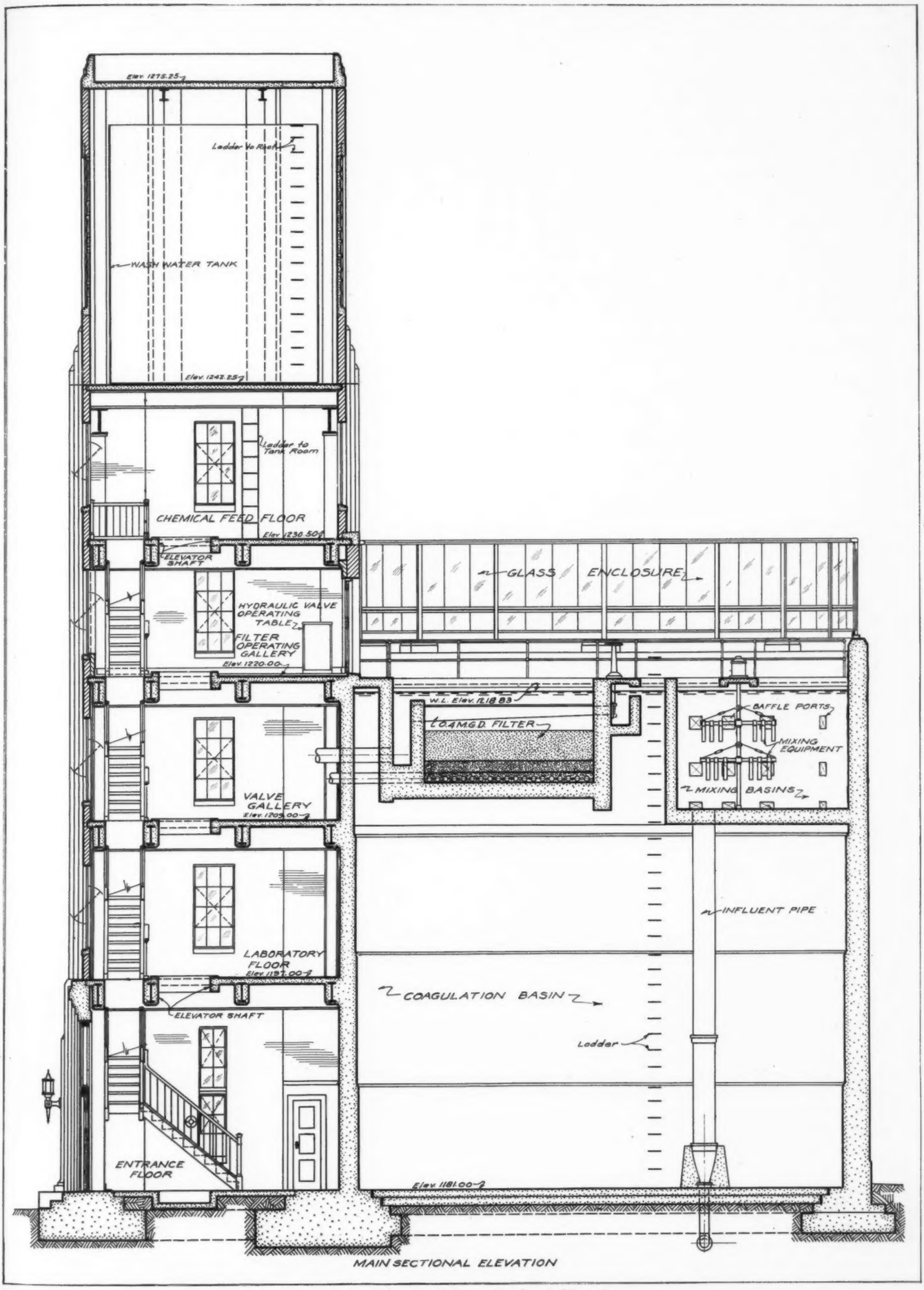
Since the auxiliary river supply has a hardness of about 9 grains, whereas the existing gravity supply is comparatively soft, provision has been made for the future installation of Zeolite softeners, the elevation of the filters being sufficient to take care of the additional head requirement for operation of the Zeolite units.

Raw water will enter the influent chamber at the top of the basin. At this point the chemicals are to be added to the water which will flow through baffled mix-

*With Wiley and Wilson, Consulting Engineers, Lynchburg, Va.



Novel Filter Plant Under Construction at Lexington, Va. (Wiley & Wilson, Engineers). The Design of This Unusual Plant Developed During an Evaluation of Several Economic and Technical Considerations Involved—Both as to Construction and as to Operation.



Lexington Filtration Plant—Sectional Elevation.

Water Works and Sewerage—May, 1936

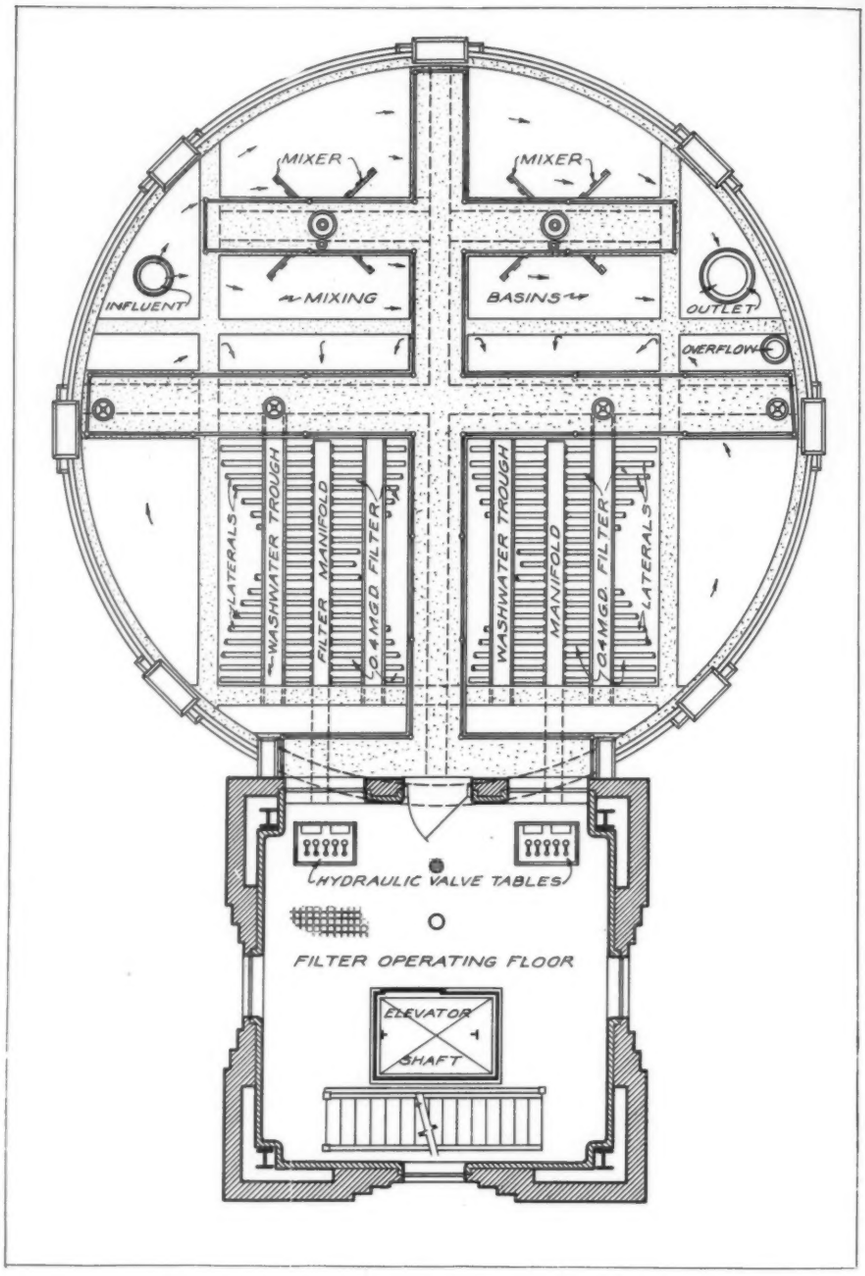
ing basins, equipped with variable speed mechanical mixers and flocculators. These basins are located so that the water is visible during the entire mixing period of forty-five minutes. The coagulated water will then flow through a downtake pipe to the bottom of the circular coagulation basin, and thence, guided by baffles to obtain a full detention period of six hours, will rise to the influent end of the gravity filter beds, located in the upper section of the coagulation tank structure. The filter and mixing basins will be enclosed in a greenhouse type of glass cover to provide light and suitable working conditions for the operators and equipment.

The Operating Tower

The tower located at the front of the plant is five stories in height, the wash water tank being placed in the top section of the structure. The structural steel framework for supporting the tank also serves as the framework for the operating tower itself. The plant is to be equipped with a small elevator for freight and passenger service and heat will be supplied by natural gas-fired unit heaters.

The first floor will serve for an entrance lobby and will provide space for the various meters. On the second floor will be located the chlorinator room and laboratory and minor items of equipment.

The third floor will constitute the valve gallery for controlling the various lines to the filters and other points. The fourth floor will be the filter operating floor, on which will be located the hydraulic valve operating tables and indicating and recording gages and equipment. From this gallery a door leads to the glass enclosure over the filters and mixing basins. The fifth floor will serve as a chemical feed floor, on which will be located the various feeders and chemical storage space and also the elevator control equipment.



The Lexington Plant Plan, Showing Location of Filters and Filter Operating Gallery on 4th Floor

Due to the relatively small capacity of that portion of the coagulating basin represented by the permissible water level variations at the top of the tank, and the difficulty of supplying water to the basin from the gravity supply without waste from overflowing, a compensating float control has been developed to operate in conjunction with the filter rate controllers in such a way that the filtering rate will be regulated to the rate of supply of raw water, which rate of supply will be adjusted to a point within the normal capacity of the filters. In other words, the rate controllers which are set for a given maximum will be compensated by the water level in the coagulating basin to reduce the rate of flow by the lowering of the water level in the coagulating basin in such a way that the filtering rate will be within the rate at which water is supplied to the basin without the waste of water through the overflow connection. With this arrangement, the water level in the basin, as well as in the filter tanks, is maintained at a uniform elevation without waste of raw water from the mountain supply, which it is desired to conserve to the fullest possible extent. This arrangement will also conserve the emergency water supply without excessive pumping.

The tower structure will be built of light buff colored brick and the remainder of the plant will be of concrete and steel, all of which have been given suitable but simple architectural treatment to present as pleasing appearance as possible within the limited appropriation available for the purpose.

The plant will have a complete laboratory and will serve as a practical operating plant for the sanitary engineering class of the Virginia Military Institute, which in itself justified the installation of a plant of the most efficient design.

Diesel Power for Pumping

Owing to the fact that the auxiliary supply pumping station at the river will be used for a very small proportion of the time, and its power requirements being rather large, involving heavy standby charges, it was decided to use pumps of the Diesel engine-driven type at considerably increased first cost. This pumping equipment is to be housed in a neat brick building, located on elevated ground near the bank of the stream with a 6 ft. by 8 ft. intake well extending down below the low water level and supplied through an 18 in. cast iron intake pipe with suitable screens. A low concrete dam (barrier) will be placed across the width of the stream to lead the water to a self-cleaning sluice-way or intake passage near the pumping station, where a sufficient depth of water can be provided for the intake line during the lowest water periods. The distance from the pumping station to the filter-plant is approximately 7,000 feet, while the elevation from the stream level to the top of the coagulating basin is approximately 318 feet.

The water works system is under the management of Mr. H. B. Rice, Superintendent of Public Works. Wiley & Wilson, of Lynchburg and Richmond, Va., are the Consulting Engineers.

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ACTIVATED ALUM LAUNCHES TRAVELING LABORATORY

A development of interest in the field of water purification is the announcement, from F. E. Stuart, of the "launching" of a traveling water works laboratory by the Activated Alum Corp. of New York, which has recently placed Mr. Stuart at the head of its Development Department.

This interesting unit consists of a 19 foot Curtiss Aero-Car which contains the latest type of equipment available for the study of treatment methods and operating efficiencies at water and waste treatment plants. The results of studies made in the field will become available to all water works superintendents, chemists, and engineers interested in coagulation control and taste and odor improvement. From studies of actal conditions in the field with the traveling laboratory should come a better understanding of coagulation and taste and odor control—using established and improved products.

Besides containing the latest type equipment (some especially designed for research work) the unit will carry all available types of coagulants and activated carbons for making comparisons. Amongst these will be Activated's novel "BLACK ALUM" which is standard filter alum into which has been incorporated powdered activated carbon. The importance of close coagulation control, utilizing the effectiveness of activated carbon absorption in the coagulation process, will be tested and demonstrated in an attempt to prove the economies resulting from good coagulation and improved coagulants.

Activated Alum's Traveling Laboratory.
(Photo by Courtesy, West Palm Beach Water Co.)

Amongst the interesting units of equipment in the floating laboratory is a new laboratory flocculating machine, designed by C. F. Bingham of Richmond and built by Phipps & Bird, which has several distinctive features. (A picture and description appears elsewhere in this issue.—Ed.) Other apparatus for flocculation tests is a newly designed Air-Mixer—utilizing a small electric blower and porous diffusion plates, such as those used in activated sludge plants. This Air-Mixer is to be used in comparing mechanical mixing with air mixing —particularly in the treatment of trade wastes and domestic sewage.

Included in the routine laboratory apparatus are several pieces of equipment especially valuable in field work, such as—the latest type Hellige Aqua Tester, and Hellige Turbidimeter, for determining the slightest traces of turbidity and color, and a rather complete set of Taylor Slide Comparators for pH, chlorine, iron, etc. For determining the extent to which "Free Alum" is left after treatment the useful Baldwin Residual Alumina Set, produced by Phipps and Bird, is to be employed.

Aside from the equipment commercially available, some has been especially designed for this unit. The laboratory contains a complete taste and odor control section for the purpose of determining the effectiveness of coagulation on taste removal and the efficiency of various coagulants, chlorine, activated carbons. All of the odor detection equipment is of Pyrex glass which has proved superior in odor evaluation work.

Additional features incorporated in the design of the Aero-Car mobile laboratory are the following: Aluminum foil heat insulation; sound-proofing and insulating felt between outer and inner body; water supply at 70 pounds pressure; porcelain sink; lavatory; complete galley; refrigerator; disappearing Pullman type berths; 6 and 110 volt electric system; built in radio; typewriter desk, and a built in library, which will be kept up to date with the latest books and manufacturers' pamphlets on water and sewage treatment.

▼

Fifth Virginia Short School For Waterworks Men Held at Farmville

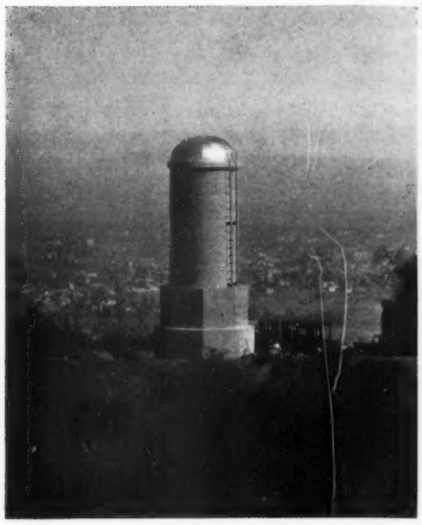
The fifth of ten proposed zone schools for water works men was held at Farmville, Virginia, on May 7 and 8. Each of the schools is designed to cover problems peculiar to the zone in which the school is held.

These schools are sponsored by the Virginia Section, A. W. W. A., with the co-operation of the State Department of Health, League of Virginia Municipalities, State Division of Trade and Industrial Education, Virginia Polytechnic Institute, Virginia Military Institute and the University of Virginia.

The schools are planned and supervised by Major Richard Messer, Director Sanitary Engineering, Virginia State Health Department.

LOS ANGELES WATER SUPPLY

In Pictorial Review



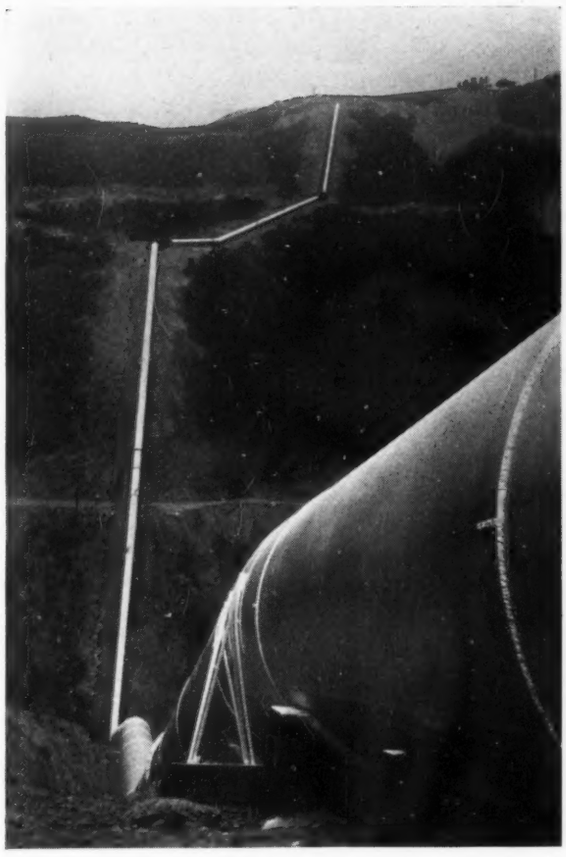
Lookout Mountain Tank

One of the Main Pumping Stations, North Hollywood

A Los Angeles Chlorinating Station, Griffith Park

Why Snow Means So Much to "The City of the Angels"

Los Angeles secures the major portion of its water supply from the runoff of snow blanketed Sierra Nevada peaks. Deep snows mean full reservoirs and less pumping

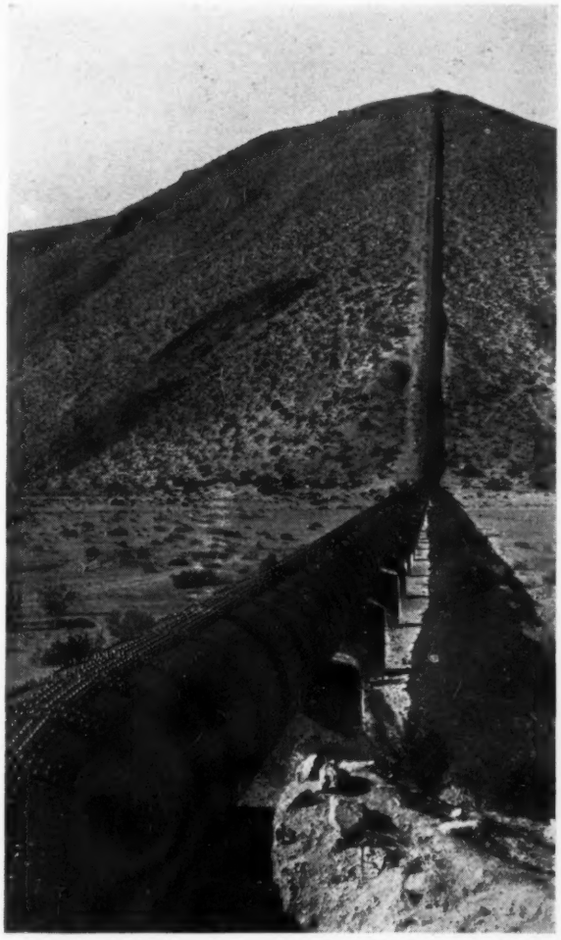


A Spectacular Piece of Pipe Lining—Not Without Its Problems

A single pipe line serves both as inlet and outlet to Bouquet Canyon Reservoir, newest and second largest of the storage basins in the Los Angeles water works. The pipe line (Aluminum painted to minimize heat absorption) connects main Aqueduct line with reservoir at a point above the municipal power plants in San Francisquito Canyon, 45 miles north of the city. Bouquet Reservoir has a capacity of 36,500 acre feet. In the East that would be practically 12 billion gallons

A Chlorinating Station

A combined pumping plant and chlorinating station at Hollywood Reservoir is one of the newest installations of this character in the Los Angeles municipal water system. Installed here are the new Residual Chlorinators which automatically make residual chlorine tests and feed chlorine to maintain the desired residual and precision control

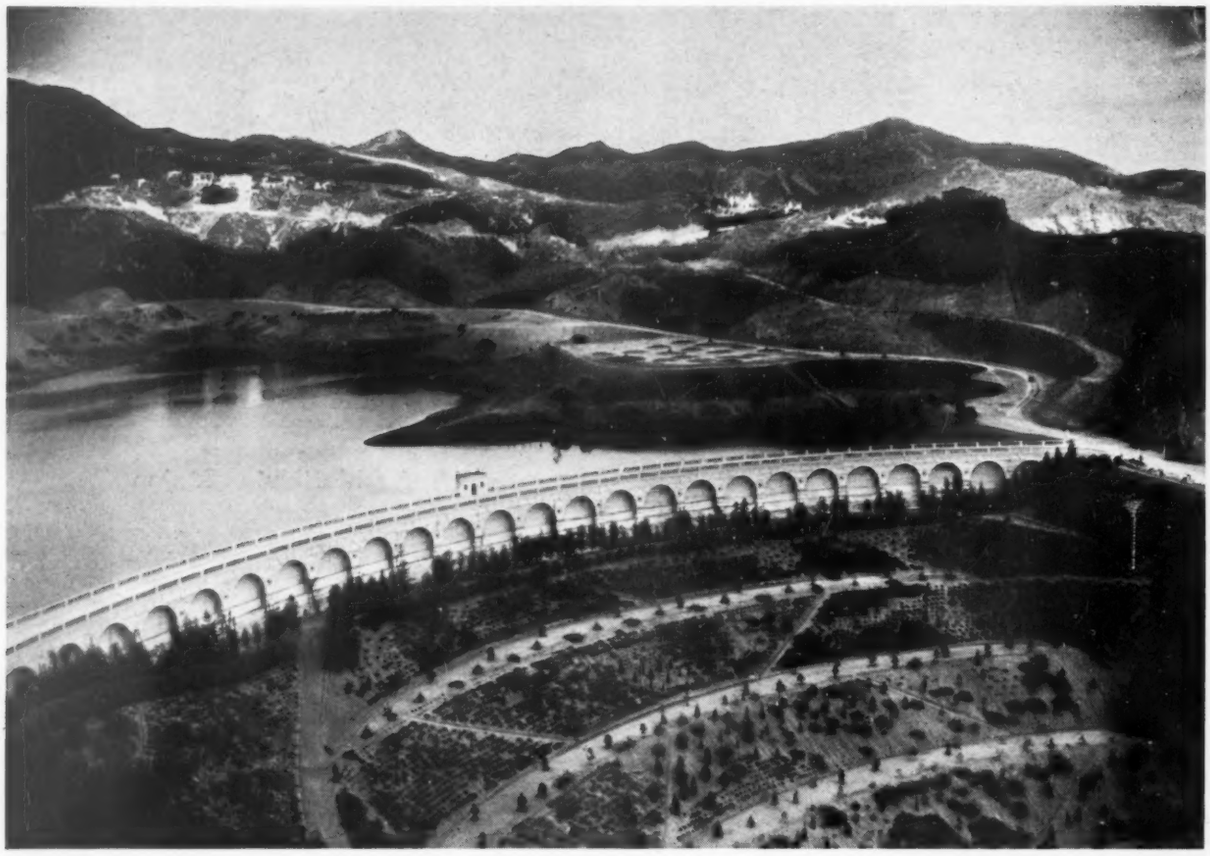


The Famous Jawbone Siphon

Jawbone Siphon is a unit in the 238 mile Aqueduct system that delivers water from High Sierra sources in Owens Valley to Los Angeles. The entire system is gravity flow, and the drop is utilized at five points to generate electricity for the municipal electric utility

Los Angeles' Water Palace

The Bureau of Water Supply's Exhibit at the San Diego Exposition in 1935

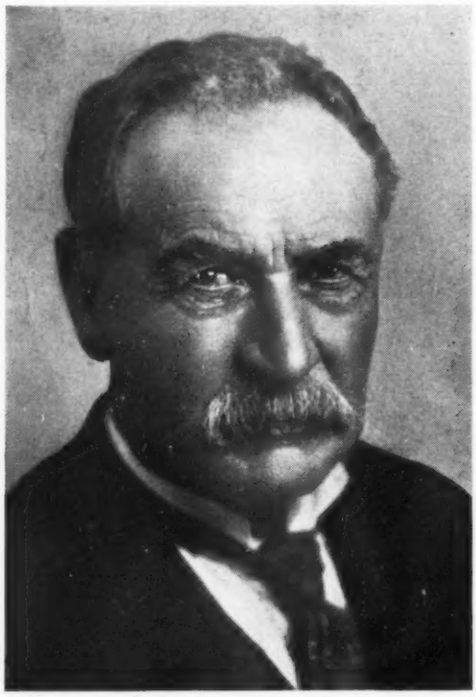


A Dam in a Famed Spot, Named for a Famous Water Engineer

Mulholland Dam, showing new landscaping of earth-fill placed in front of the concrete structure that overlooks Hollywood, and provides closein storage facilities. This dam, a beautiful piece of construction, was later backed with the earth-fill in order to allay fears of America's Movie Colony as to its safety

H. A. Van Norman

Chief Engineer and General Manager of the Water Bureau, was Assistant Chief during construction of the Aqueduct. (President, California Section A.W.W.A.)



The Late William Mulholland

He rose from a Ditch Tender to Chief Engineer and Builder of Los Angeles' Aqueduct System

William W. Hurlbut

Engineer of Water Works, Los Angeles. (President-elect of A.W.W.A.)

40 TO 1
THE OLD WAY and the NEW
SHOWING
the relative space required for drying sludge on sand filter beds in a city of 100,000 population, contrasted with that occupied by the Nichols Herreshoff Incinerator to assure *complete* disposal. The sludge bed area is approximately 100,000 sq. ft. and the incinerator area about 2,500 sq. ft. . . . . in the ratio of 40 to 1.

NO better evidence shows the compactness of a Nichols Herreshoff Sewage Sludge Incinerator installation than the comparative illustrations herewith. They graphically visualize the economy of space made possible by this improved, scientific way to dispose of sewage sludge solids by *burning*. The resulting residue is a dry, odorless, virtually inorganic ash. Minimum labor and maintenance costs also assure maximum economy of operation.

Engineers and public officials interested in solving municipal waste disposal problems by this economical, sanitary method are invited to send for more complete details.

NICHOLS HERRESHOFF
SEWAGE SLUDGE
INCINERATOR

NICHOLS ENGINEERING & RESEARCH CORP.
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PACIFIC FOUNDRY CO., LTD.
2100 NINETEENTH STREET, SAN FRANCISCO

WPA project No. 2236, Fresno, California; Jean Vincent, Director of Public Works. One mile of 30-in. reinforced concrete sewer pipe connects airport to 48-in. concrete outfall built in 1917. Maximum cut on new project, 12 ft.

FRESNO LOOKED AT PAST PERFORMANCE AND CHOSE *Concrete Pipe* FOR ITS NEWEST SEWER PROJECT

FRESNO'S WPA project begun early in 1936 calls for one mile of 30-inch concrete pipe running from the airport to a 48-inch concrete pipe outfall sewer built in 1917.

Concrete pipe was selected because of the excellent service record of this older sewer, which was built with 5-inch walls and runs one-half to two-thirds full except under rare storm conditions, with 2½ feet per second average velocities. The old pipe was found to be in perfect condition after 19 years of service.

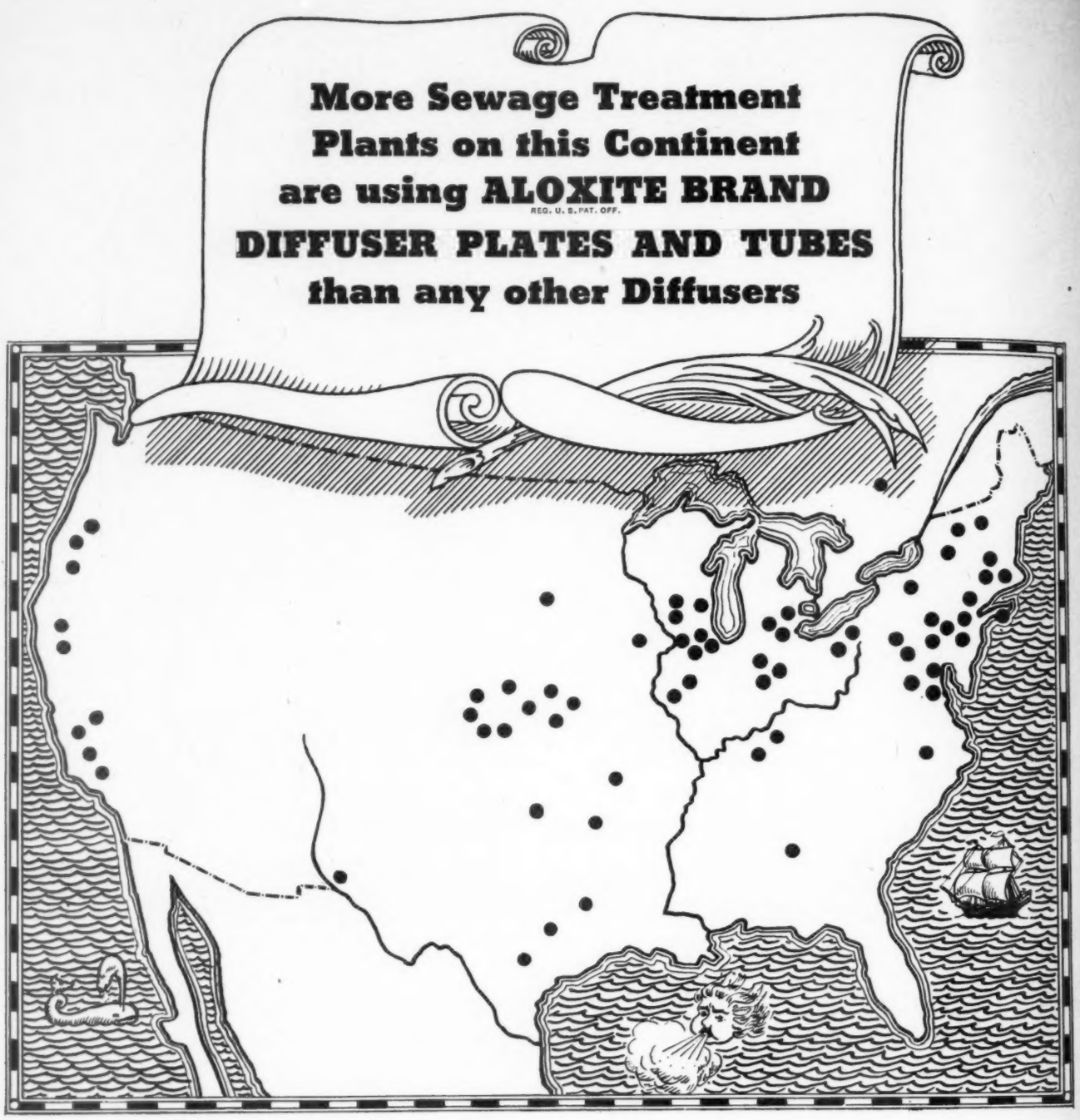
Fresno has nearly 25 miles of concrete pipe sewers, all in first class condition.

Satisfactory sewer performance requires good materials plus proper design, construction and operation. That means the use of concrete, and the supervision of an experienced sanitary engineer. His service is cheap insurance on the success of these important jobs.

Write for booklets "*Monolithic Concrete Sewers*" and "*Concrete Pipe Sewers*," providing helpful data on the use of concrete in sewers. Free upon request.

PORTLAND CEMENT ASSOCIATION

Dept. A5-29, 33 W. Grand Avenue, Chicago, Ill.


More Sewage Treatment
Plants on this Continent
are using ALOXITE BRAND
REG. U. S. PAT. OFF.
DIFFUSER PLATES AND TUBES
than any other Diffusers

THE fact that so many sewage treatment plants use Aloxite Brand Diffuser Mediums is significant. It means that Aloxite Brand Diffusers have proved their efficiency by performance.

It means that skilled research and experienced engineering service have combined in the production and application of these products of superior quality and proved characteristics.

Write our Sanitary and Filtration Department for information on design, specifications and engineering data on the application of these diffuser mediums in sewage and water plants.

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SOME FEATURES OF NEW WATER SUPPLY PROJECT AT FORT SMITH, ARK.

Twenty-Three Mile Main Involves Combination of Bitumastic-Lined Steel and Cement-Lined Cast-Iron Pipe. Filtration Involves Coagulation With Chlorinated Iron

By W. R. HOLWAY, C.E.*

A NEW water supply for the city of Forth Smith, Arkansas, a city of 35,000 population, is now being completed, consisting of an earth dam, filter plant, supply pipe line, and distribution main extensions.

W. R. Holway

The city's present source of supply, the Poteau River, has in recent years become silt-laden and polluted with wastes from the coal mines. Also, at flood times the Arkansas River, into which the Poteau flows, backs up into the mouth of the latter stream so far that its high salt content contaminates the city's water supply until it is practically unfit for use as a potable supply. The Poteau water at present is pumped to the low-level areas of the city and re-pumped to the high levels, and this new supply, which flows by gravity into the city's present reservoirs, calls for none of this expense, a saving which will pay for the new system in thirty years.

Dam and Reservoir

The location of the new storage reservoir, 650 acres in area with a storage capacity of 6,000,000 gallons, is twenty-three miles north of Fort Smith, in the Boston Range of the Ozark Mountains. The dam impounds the water of Clear Creek, which drains an area of 65 square miles of mountainous, timbered country. The dam is 2,000 ft. long and 90 ft. high, and is composed of earth and rock fill, the downstream section being composed of semi-pervious material and the upstream section of impervious earth excavated from borrow pits in the reservoir basin and from the spillway. The total amount of embankment is 1,000,000 cubic yards. The upstream side is heavily rip-rapped with stone taken from the spillway section, large pieces of this stone are also used for the guard rail along the roadway on the top of the dam. The spillway is over the sandstone ledges at the west end of the dam, the spill falling over a curved concrete weir 420 feet long and following the curving channel of the spillway to meet the stream again 1,500 feet below the dam. The inside slope of the channel is protected by large blocks of masonry concreted together. This rock is also excavated from the spillway section. A new road and two concrete arch bridges will bring sightseers to the shores of the lake and up to national Highway 71 at the top of the mountain. This lake will be one of the beauty spots of the Ozarks.

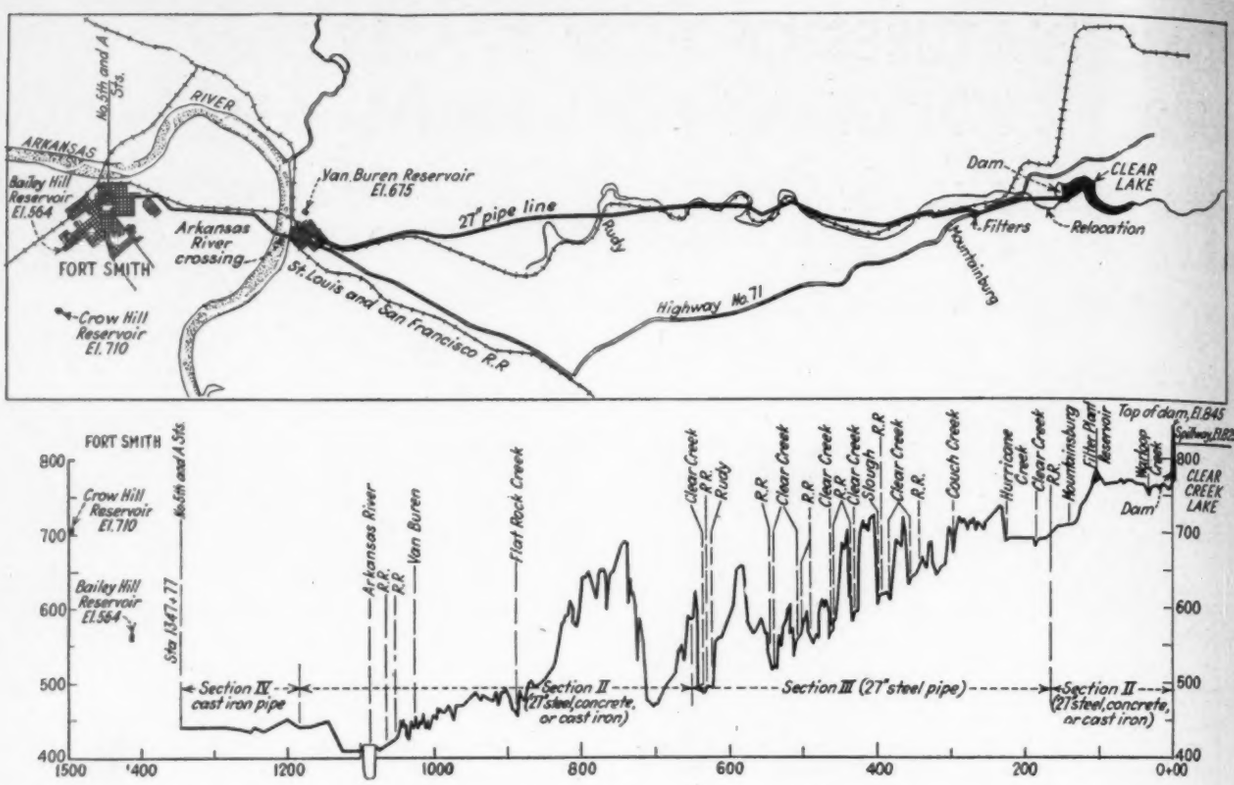
*Consulting Engineer, Tulsa, Okla.

Filter Plant

A mile below the dam is located the filter plant, a modern 6 M.G.D. rapid-sand plant with four filter units. A 30-kw. generator driven by a Fairbanks-Morse Diesel engine will supply power for operating the chemical elevator and emergency power for the plant. The water from the pipe line operates a hydraulic turbine which will supply all the power and lights for the plant and power for pumping the washwater. Lime and ferric chloride are the coagulating agents to be used, the latter being produced at the plant from chlorine and scrap iron. Ammonia and chlorine treatment will be used when necessary. Complete mechanical mixing is provided with a mixing period of thirty minutes; the two settling basins provide a detention period of six hours each. The washwater tank is of reinforced concrete and is located on a hill back of the plant. The filtered water is stored in a million-gallon concrete covered reservoir of unusual design located a short distance beyond the settling basins.

The filter plant building is built of stone excavated on the site, and the settling basins are also faced with this stone. This is in keeping with the location of this plant against a wooded hill. Because of the distance from the city and its location in the mountains, resi-

The Initial Blast on One of the Nine River Crossings



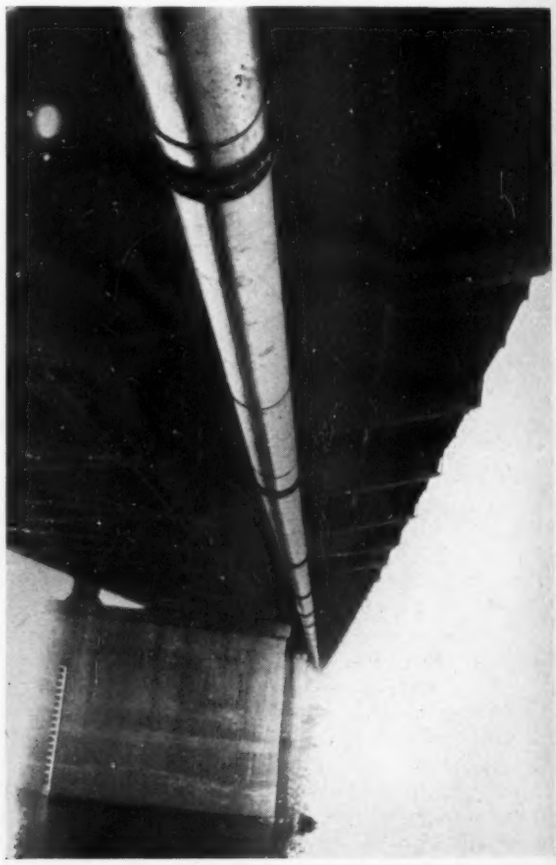
Plan and Profile of the 23 Mile Pipe Line of the New Water Supply Project for Fort Smith, Ark.
(Courtesy Eng. News-Record)

dences for the operators were also built, these too out of native stone with red tile roofs, to match the filter plant building. The result is an attractive and unusual plant in its appearance. The architect was John Duncan Forsyth of Tulsa, Oklahoma.

The Pipe Line

The pipe line on this project was divided into three sections. The city end of the line was specified to be cement-lined cast iron pipe to conform to the other distribution lines of the city. Nine miles of the central portion of the supply line was specified to be welded steel either 27 inches in diameter with a lining of Bitumastic enamel; or, to be 30 inches in diameter with the ordinary dipped coating. The reason for the choice of

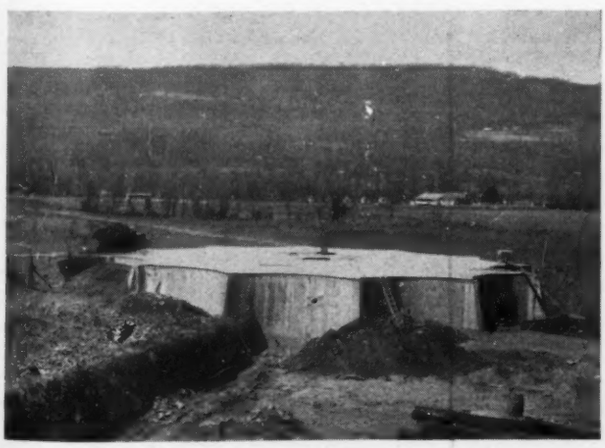
27-In. Pipe Ready to Be Lowered Into River Crossing, Fort Smith Pipeline



2,500 Ft. Section of 27-In. Pipe Line Suspended Under Bridge of Arkansas River. Forty-Foot Sections Joined with Dresser Couplings

27-In. Pipeline Showing Dresser Coupling Used in Combination with Welded Joints, Fort Smith, Ark.

steel pipe only for this section of the pipe line was due to the fact that this nine miles of line was through very rugged mountainous country and included nine river crossings. This river has changed its course in the valley several times during the past few years and it was decided that it would be unsafe to use any pipe which had joints that might be disturbed should the river change its present course. The greater part of this section of the line operates under at least 200 pounds to the square inch of pressure. For the remainder of the supply line (the third section) alternate bids were asked on the same type of steel pipe, as on the central section, and also on cement lined cast iron pipe, 27 inches in diameter. In addition bids were asked on reinforced concrete cylinder pipe of the same diameter. The specifications provided for such thicknesses of the various pipes that they were all considered equal.



Clear Well Reservoir at Filter Plant, Fort Smith, Ark.

Contracts were awarded for steel pipe 27 inches in diameter with Bitumastic spun enamel on the two sections of the supply line. The steel pipe was manufactured by the Taylor Forge and Pipe Company and the cast iron pipe was furnished by the American Cast Iron Pipe Company.

Across the Arkansas River the pipe was made of ⅜-inch plates and long-sleeve couplings were installed at the two ends of the lift span of the combined railroad and highway bridge under which the pipe line is suspended. At every forty feet of the bridge length Dresser couplings were placed so that the pipe line may expand and contract with the bridge. Dresser couplings were used throughout the line, as well as welded joints.

Water Hammer and Surge Suppressors

Six automatic control valves were installed in the line in order to reduce surge and water hammer to a minimum. These were installed by S. Morgan Smith Co. These valves float in the line and not only cut down the surge but are designed to automatically close in case of a major break in the line below any one of the valves. There are also 2-inch air vacuum valves at all important summits of the line and 8-inch blow-off at the important depressions. The pipe line is entirely buried in the ground, except for the Arkansas River crossing, the minimum cover being two and one-half feet.

The complete cost of this project is $1,700,000. To finance it revenue bonds were issued by the city and a 30 per cent grant was secured from the Federal Public Works Administration.

The writer has served as engineer in charge of design and construction on this project. The resident engineer was W. T. Barry of Fort Smith. The dam was built by M. E. Gillioz of Monett, Missouri, as contractor and W. R. Grimshaw, of Tulsa, built the filter plant. The 23-mile pipe line was laid by Williams Brothers, of Tulsa, and the cast iron mains, by B. & M. Construction Corporation, of Oklahoma City, Oklahoma. Mr. C. S. Young was P.W.A. resident engineer.

▼

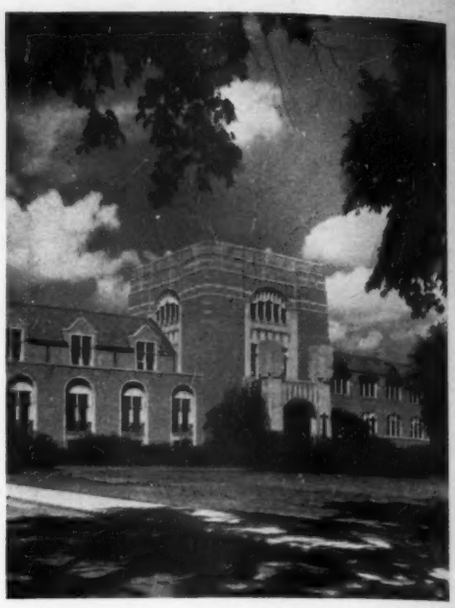
"4" States Section A. W. W. A. Names Hechmer, Sec'y; Becker A. W. W. A. Director

At the recent meeting of the 4 States Section of A. W. W. A., Chas. H. Becker, who has served as its Secretary-Treasurer for several years, was honored by being elected a member of the Board of Directors of the American Water Works Association, to represent the 4 States Section, the term of Seth M. Van Loan having expired.

The worthy successor elected to the vacated office of Secretary-Treasurer is Carl A. Heckmer, Department Engineer, Washington Suburban Sanitary District, who has long been one of the "wheel horses" of the 4 States Section and active in A. W. W. A. affairs.

To the office of Chairman of the Section was elected Ezra B. Whitman, prominent Consulting Engineer of Baltimore, Md., and his Vice is Harry M. Freeburn, District Engineer, Penna. State Department of Health, Philadelphia, Pa.

Elected Trustees were: I. M. Glace, Cons. Engr., Harrisburg, Pa.; C. J. Lauter of Washington, D. C., and Leon A. Small, Baltimore's Water Engineer.



Purdue Memorial Univ. Here the Indiana Section Meets, Eats and Sleeps—Comfortably, Economically

INDIANA SECTION A.W.W.A. MEETS AT PURDUE

WITH the best attended meeting for the past several years, Indiana's Section of the American Water Works Association held its 29th annual meeting on April 7th-9th at East Lafayette, Ind., within the halls of Purdue University. The official attendance was better than 200.

The custom of the Section is to alternate between Indianapolis and Purdue University in holding its meetings. And, no little reason for selecting the latter is the way in which W. A. Knapp, Assistant Dean of Engineering, handles the meeting arrangements and provides the program facilities and entertainment. The custom of holding sectional meetings and short schools at State Colleges and Universities is growing—and, justifiably so. The meeting at Purdue is further evidence of the merit of so doing.

School for Superintendents

The meeting opened with a so called **"School for Water Superintendents"** which was in reality an afternoon session in which short papers and talks of interest to superintendents were presented and informally discussed.

The first "lecturer" was PROF. W. E. HOWLAND (Purdue University), who demonstrated the performance of a centrifugal pump and the general principles by which pump characteristics may be varied by changing the clearances and shape of the impeller.—An instructive talk, simply illustrated.

Cecil K. Calvert, Indianapolis, Retiring President

B. A. Poole, Indianapolis, President-Elect

"Meter Construction and Operation" was discussed by F. A. SCHAEFER, Supt. Public Service Company, of New Albany. He pointed out the necessity, in modern usage of water, to test all meters on a 1-32 inch stream. To increase meter accuracy at minor flows he gave some useful pointers.

"Meter Sizing" was dealt with by H. W. NIEMEYER, Asst. Supt. of Distribution, Indianapolis Water Company. He emphasized the fact that the use of oversized meters was a common source of loss of revenue through failure to register that continuous waste which is likely to be less than the minimum which is required to operate the meter mechanism. Demand studies of single dwellings, using tank type toilets, had shown that ⅝ inch meters will give adequate service without excessive pressure loss. Demand studies of multiple family dwellings had shown that one 48 apartment building, using tank toilets, required a maximum flow of only 27.5 g.p.m. and a night flow of 2.6 g.p.m. A 45-unit building with flush-valve toilets, had presented a maximum demand of 65 g.p.m. and a night flow of 1.8 g.p.m. In these cases only 27.5 and 40.5 per cent, respectively, of the capacity of the meters installed was reached thus indicating the feasible use of smaller meters so that closer registration of the minor and average flows would be obtained. In addition, oversized meters were productive of further losses, through increased investment and maintenance costs. More attention to proper meter sizing, in accord with water flow demands, seemed justified by Mr. Niemeyer. Others had to agree.

In stressing the importance of **"Location Records for Mains and Meters,"** by P. C. GALE, Supt. Water Works, Michigan City, stated that contrary to the practice, which is too often the case, location records covering water systems should not be kept in the head of the superintendent who may some day "lose his head," (politically speaking), or forget (humanly speaking). On taking over the operation of the Michigan City Water Works, he had found the only existing distribution system records to be pencilled notations in note books. A few sketches, unsigned, undated, and with no dimensions, offered very little help. After two years (with the aid of C. W. A.) very complete distribution records had now been made and their value had been

Prof. W. A. Knapp, Purdue University, in Charge of Arrangements

John A. Bruhn, Indianapolis, Secy.-Treas.

thoroughly demonstrated during the past severe winter.

Discussion disclosed that some water departments keep distribution records in the office in charge of some one who can give information to the crews on the job by telephone. Others maintain blue-printed maps in metal tubes on all emergency and repair trucks. A combination of the two has its merits over either alone.

In discussing the **"Value of Standards of Practice"** L. F. FINCH, Cons. Engr., Indianapolis, pointed out that standard practice, when followed in operation, prevents such failures as running out of chlorine and other chemicals, leaving unrepaired any "out-of-order" equipment, and missing the recording of operating data.

H. S. Morse, Manager, Indianapolis Water Co., commented that they kept a code-book which outlines procedure in all kinds of situations, even to specifying the kind and color of paint to be used in various places. The "code" could never be complete because of changes from time to time, as conditions warranted. However, it served as a valuable guide and a record of previous decisions.

E. F. KINNEY, Wallace and Tiernan Co., Indianapolis, outlined suggested practices in the **"Practical and Safe Handling of Chlorine"** in the water plant. He emphasized the danger in locating chlorinating equipment or chlorine below ground without adequate provision for gas removal. He warned operators to see that gas masks were of the right type and in good condition. Stated, in substance, that an ounce of precaution was worth a pound of regrets.

Cold Weather Troubles

Operators from thirty cities and towns of Indiana reported cold weather troubles at the round-table discussion. Discussion from the floor included the relative merits of meter pit diameters and depths, the use of double lids as frost protection, the thawing of services with arc welding machines. W. C. MABEE, Chief Engineer, Indianapolis Water Company, who led the discussion, presented charts, one showing the relation between cumulative freezing degree days and the cumulative number of frozen services in Indianapolis. There appeared to be a time lag of about three weeks between the onset of sub-zero temperature and service trouble. Concerning the value of snow as an insulating agent, one superintendent reported that one agency of his city urged the owners of property to allow the snow to remain on side-walks as a frost protection to their water service, while another agency threatened prosecution if the snow was not removed. Was the snow removed? Did the services freeze? Our reporter does not say.

Officers and Awards

Officers announced elected for the ensuing year are:

President, B. A. Poole, State Dept. Health, Indianapolis.

Vice-President, John Ford, Ford Meter Box Company, Wabash.

Sec'y-Teas., John Bruhn, Indianapolis Water Co., Indianapolis.

A. W. W. A. Director, W. C. Mabee,* Chief Engineer, Indianapolis Water Company.

(*Appointed to complete the term of H. S. Morse, Mgr. Indianapolis Water Company, resigned.)

Having displayed the successful "gadgets," entered in the interesting "Gadget Contest," awards were as follows:

First Prize—($7.00) To, H. E. Venner, Public Service Co., New Albany, Ind., for his "wrench for operating packing gland nuts on main-line valves."

Second Prize—($3.00) To, Geo. T. Gilbert of Indianapolis, for his "Special wrench for removing meter, piping and ells from meter-boxes."

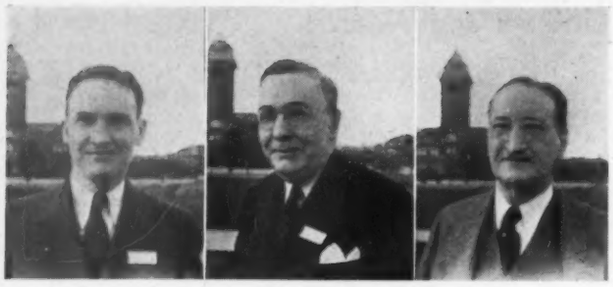
Technical Sessions

(President—C. K. Calvert, Presiding)

The opening paper was a masterful contribution by FRANK R. SHAW, San. Engr., U. S. Public Health Service, Chicago (Ill.), who discussed the possibilities of **"Conserving Our National Water Resources."** He enumerated the acts of a man which had been responsible for the floods, droughts and for our "open-sewers" where pure streams once existed. He outlined possible methods of at least a partial return to natural conditions and abundance of clean water for all. Mr. Shaw reviewed the Federal development looking toward a coordinated and planned effort of state and local authorities toward recovery from our seriously polluted water-ways. He quoted important parts of the recommendations of the Special Advisory Committee on Water Pollution, made to the National Resources Board, which wishes to avoid usurping authorities now held by state agencies. Mr. Shaw cited the marked progress made in advancing sewage treatment during the past 2 years and the work under way or completed in reducing industrial pollution. The valuable stream pollution work of the U. S. Public Health Service was briefly reviewed and Mr. Shaw concluded that the Federal Government could do most by supplying state assistance where desired. This, through promotional endeavors, investigation, research, establishment of standards for water quality and effluents, and in supplying financial aid through grant or otherwise. The last might be expected to also stimulate industrial-waste treatment in a manner

Frank C. Jordan, Indianapolis

Prof. F. M. Dawson, Univ. of Wisconsin



John L. Ford, Ford Meter Box Co., Wabash, Ind. (Vice-President of the Section); Harry E. Jordan, Chem. Engr., Indianapolis Water Co. (Past Pres., A. W. W. A.; Diven Medalist, etc., etc.); W. C. Mabee, Chief Engr., Indianapolis Water Co. (A. W. W. A. Director, Rep. Indiana Sect.)

similar to that secured through Federal grant agencies during the past two years in domestic sewage treatment.

In discussion, B. A. Poole, Chief Engr., Indiana State Dept. of Health, felt that Federal assistance, as outlined by Mr. Shaw, should be very productive; and, whereas, Indiana had progressed somewhat, it could have gone further if most of the Indiana applications for Federal grants (or loans and grants) had been approved, or reached on the list.

Another number one "paper" was a highly instructive talk by PROFESSOR F. M. DAWSON, head of Hydraulic and Sanitary Engineering at the University of Wisconsin. He dealt with a topic of current concern to, and activity on the part of, many water works operators—that of **"Cross Connections in Water Supply Systems."** More particularly did he discuss those difficult to discover and eliminate, such as the multitudinous cross-connections with the sanitary plumbing within buildings. Professor Dawson's enlightening discussion, supported by blackboard sketches, was based on seven years of experimental investigation within his department at the University of Wisconsin, the results of which have become available to a major extent in the revised University of Wisconsin Engineering Bulletin—"Cross Connections in Plumbing and Water Supply Systems." (We take this opportunity to recommend to every Water Company or Water Department head that he secure a copy of this authoritative and informative bulletin by requesting it from Professor Dawson or L. F. Warrick, State Sanitary Engineer, Madison, Wisc. The charge of 25 cents per copy is nominal and merely pays for the second printing, made necessary when the demand quickly exhausted the first printing.—Editor.)

Professor Dawson emphasized the dangers (little appreciated) from the possible back-syphonage of the contents of a variety of sanitary fixtures whenever inadequate pressure and simultaneous heavy drafts on lower floors created a partial vacuum within the system above. Less potentially hazardous, but more seriously so, was the sucking of contamination into the mains during heavy fire draughts, emptying mains for repairs or as the result of breaks. He felt that the water-works management had more than passing interest in seeing that the purified water served by it should not be contaminated beyond the curb-cock by faulty plumbing arrangements. If not directly attainable, then through efforts in cooperation with local health and plumbing inspection agencies the water-works authorities could do much to secure correction of such conditions and prevention of faulty installations in the future. As an outgrowth of the Wisconsin studies, syphon-proof fixtures could now be obtained from the leading manufacturers.

The interest in Professor Dawson's clear cut presentation was evidenced by the need for adjournment for sustenance and continuation of discussion and questions in the following session. Fort Wayne, reporting through Mr. Ralph Hoot, was justly proud of its accomplishments in having secured a 100 per cent effective severance of industrial cross connections and was complimented by the State Department of Health, through B. A. Poole, Chief Engineer, as having set up a mark in this direction for large cities, where the difficulties of correction are far greater than in smaller ones.

In this connection attention was directed to an article in WATER WORKS AND SEWERAGE for April, by Stephen A. Taylor, Superintendent of Water at New Bedford, Mass. It is the first published account of "Regulation of Water Piping Within Buildings" by the local water works authority. The article presents the covering ordinance and method of procedure. (Copies may be had upon request.—Editor.)

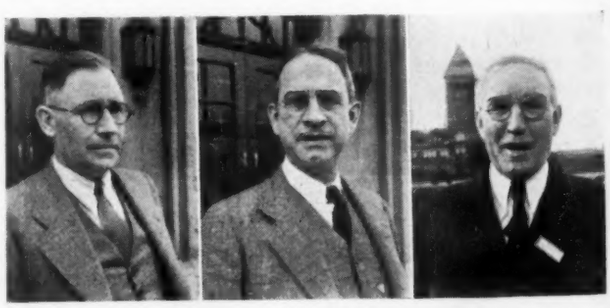
"Politics, Water Supply and Public Health," was forcefully discussed by HARRY E. JORDAN, Sanitary Engineer, Indianapolis Water Company and Past President of A. W. W. A. He revealed that political turnover affected to some extent, if not seriously so, 4 out of every 5 small town municipal water works. In larger cities such was not so prevalent, but should not exist at all. The failure of purification processes (frequently causing epidemics) could be laid at the door of the political spoils system in numerous cases on record. Between safe and dangerous operation of water works the State Sanitary Engineering Division was usually the single agency available to safeguard the public in the water supply field. Administrators in state government, said Mr. Jordan, would do well to recognize this fact more adequately, and he was strong in his praise of the good done by men of outstanding personality holding positions as State Sanitary Engineers. such men, he commented, were worth whatever it might take to secure their services because bearing, brains and personality secured recognition of the true value of the agency. He recommended the following considerations to administrative heads, as a betterment highly desirable.

(a) That the staffs of Engineering Divisions of State Health Departments be increased to a more adequate extent.

(b) That the compensation set be increased to attract the highest type individuals to these positions.

(c) That Municipal Health Departments increase their activities in bettering water supply and particularly looking toward elimination of plumbing cross-connection hazards.

(d) That efforts be put forth to secure a better understanding of the public as to the responsibilities of



Walter B. Jenkins, Supt., Water, Oakland City, Ind. (Protects tanks with crude oil); Chas. Brossman, Cons. Engr., Indianapolis (Knows the value of elevated storage); Chas. S. Chamberlain, Supt., Water, Rensselaer, Ind. (Cashes his water bills at banks—customers agree)

H. G. Coughlen, Asst. Supt., Pumping, Ind. Water Co.; Paul C. Loux, Supt., Purification, Anderson, Ind.; Homer Rupard, Prin. Asst. Engr., Ind. Water Co.

the water utility, the follies of political interference, and the need for dependable experienced operators.

(To every State Governor, Budget Director and Administrator of Public Health should go a copy of Mr. Jordan's meaningful paper as soon as reprints may become available. It may do some good. Coming from one connected with a Water Company—persecuted by regulatory agencies at times—it carries peculiar and added weight.—Editor.)

"The Value of Elevated Water Storage" was well presented by CHARLES BROSSMAN, Consulting Engineer of Indianapolis. He cited case records, drawn from representative installations, to show the advantages accruing from effectively located elevated tanks. Principally (well known to most water works engineers) these were: advantage of steady-load pumping; sustained and uniform pressures at services; adequacy of fire flows and pressures; reduced insurance rates; less sleepless hours for the water works operator; the use of maximum pump output at maximum economy; the savings from smaller sized pump-motor units acceptable in routine operation; the reduced stand-by electric charge; the ability to use larger units and shorter hours of pumping during the off-peak hours (with more economical current rate) usually at night; reduced investment in, or dependability on, duplicate and high capacity stand-by plant equipment. It was not uncommon, Mr. Brossman said, to effect through elevated storage facilities a cut of 50 per cent in electric pumping costs. The economics of elevated storage had proved itself. Witness the ease with which P. W. A. loans for such betterments had been secured on the basis of certain return on the investment and the rapid amortization possible.

CHAS. S. CHAMBERLIN, Manager of Municipal Utilities, Rensselaer, Ind., with past water company experience, vouched for all that Mr. Brossman had said. Higher and more uniform pressures, he added, produced higher water collections due to increased flows through the services—but, with it, more satisfied customers as well.

W. B. JENKINS, Superintendent, Oakland City, Ind., told of a method of protecting the interior of a new tank which involved an oil coating rather than a paint job. Crude oil placed in the dry tank was floated up as the water was admitted slowly. At the edges, the oil film seemed to be rolled onto the metal. Lowering and raising the water level, with the oil blanket present, produced the desired coating. He did not know how long it would last but it had not created any complaints of taste as might be thought. The scheme had been recommended by the tank builders. (Possibly a special oil had been used but Mr. Jenkins thought it ordinary crude oil.—Editor.)

"Methods of Producing Efficiency in Pumping Station Operation" were reviewed by H. G. COUGHLEN, Asst. Superintendent, Pumping Stations, Indianapolis Water Company, who stressed the proven value of keeping adequate daily logs at pumping stations. To do so required the use of certain indispensable instruments, preferably with recording mechanism. Some means of metering the station output *accurately* was, of course, essential—Venturi type meters being preferable, even when reciprocating pumps were utilized. Pressure gages, preferably recording, were another essential on boilers and pump discharge. A CO_2 meter on each boiler and accurate check on weight of fuel burned were others. Meter records of the water evaporated (boiler input) completed the essentials in steam plants. In his experience obsolescent equipment was the weight on the neck of "drowning" pumping stations when reckoning from an economy and efficiency point of view. Investments for modern efficient equipment and recording instruments could be proven an economy move within a short operating period. In other words, Mr. Coughlen stressed the folly of being "penny wise" when it came to operating and maintaining such costly units as power and pumping elements in the water supply business. The next most important phase of efficiency and economy production was "good-housekeeping" (upkeep) and the caliber of operating personnel. Shooting at marks set for "shift-performance" had proved ideal in large stations as a means of competition, which is always interesting if done properly.

"Publicizing the Utility" was the subject of a running talk by a public-relations expert of no mean ability—MILLER HAMILTON, Director of Publicity, Indianapolis Water Company. He presented some of the high-lights in securing water-works publicity, but warned that the first per-requisite was a good product. When the water was of high quality in all respects, then it became a salable product—not before. The next was the desire of the chief executive for publicity. Then came the training of the utility personnel—who had to make contacts with the public—the latter being a *real* foundation stone in public relations work Dealing with the public was, in essence, a fine art.

Having prepared the basic foundations—the "pretty is as pretty does" side of the picture—it was then (and only then) time to seek publicity and start to build up the "good will" structure on the foundations laid. Using the local press was then an open door, if the editors were taken into the confidence of the utility. Show the editor the makings of a good story, Mr. Hamilton said—but, have real ones in the beginning—and your effort brings results. The editor should be given advance notice when to expect a new story and he will be prepared to use it in the Sunday editions, or others most widely read.

Now concerning leaflets and pamphlets. Free literature was at a disadvantage always and unless the production had eye-appeal and a cover which creates

W. H. Durban, Supt., Water Co., Terre Haute, Ind.; P. C. Gale, Supt., Water Wks., Michigan City, Ind.; Miller Hamilton, Publicity Dir., Indianapolis Water Co.

Snapped on Purdue's Campus

(1) Hayes Kuhns, "Leadite" Co.; (2) W. A. Welch, "Nuchar"; (3) J. F. Bradley, Ch. Engr., Valparaiso; (4) B. H. Jeup, San. Engr., State Dept. Health; (5) H. J. Draves, Michigan City Water Wks.; (6) Bill Birch, "Himself," Chicago; (7) Lew Birdsall, Gen. Chemical, "Alumite," came down to see his Purdue Sophomore Son and likewise do a little conventioning

curiosity as to what's inside—it's just so much waste basket material. An example—*"What John Told Mary"* --a cover caption used by Indianapolis Water Company made the curious housewife read a well told dialogue, incidentally learning much of the technical side of water purification and distribution problems in two syllable words. Well—"Mary told John" about it that night—and so the information spreads.

Then, to demonstrate what can be accomplished with the spoken word and eye appeal, Mr. Hamilton stepped from the technical to the non-technical side of the platform and while running off a superb moving picture of several reels of the new color film, he gave a simplified lecture on the "Why and How" of the water supply storage in general; and, concluded with a specific description of the Indianapolis system and its importance and usefulness to the community. The spotless laboratories at Indianapolis certainly click with the critical public. (Indianapolis Water Company has put across the finest piece of water-works publicity ever attempted in America.—And, we may add, the most costly. But, in Indianapolis, they say that it pays. Of the municipally operated systems Los Angeles is doing the most effective job in this direction. More power to both.—Editor.)

"Collections With Minimum Friction" was the subject of a progress report of a Committee, organized by F. C. Jordan, studying the matter of improving water rent collections and reducing friction with the customer. C. W. GORIS, of the State Public Service Commission, presented the report which recommended, amongst other things, a system of guaranty of payment from non-property owners rather than the customer deposit system. Endorsement by a property owner for non-owner was usually sufficient protection. Firm but fair collection efforts (expected by the customer) should be enforced uniformity to all classes of takers as the one essential to success in keeping deficits from accumulating and thereby constantly harder for the customer to pay. The report "O.K.'d" demands for deposits and commercial takers. It recommended that, before a shut-off order for non-payment is issued, each account should be reviewed by a responsible water utility official for approval or further investigation. Routine shut-off orders were condemned as bad practice, always creating ill-will and sometimes injustice. The value of high type of personnel making contacts with the public was also stressed as a means of improving collections.

A Case of Ike and Mike

Brothers? No; not even kinfolk. (Left) Ed. F. Kinney, Wallace & Tiernan Co., Indianapolis. (Right) Tom J. Burrin, Supt., Water and Sewage, Lebanon, Ind. (If both were laughing, you'd take 'em for twins.)

Chas. S. Chamberlin, General Superintendent, Water and Light, Rensselaer, Ind., reported that they required no customer deposits; had little friction. An interesting and economical collection method was reported by Mr. Chamberlin. Listen carefully! The scheme involves a signed agreement between willing customers and the utility. It authorizes the Water and Light Department (through the City Treasurer) take over the bill to the customers' bank and there collect the amount due. The bank handles the bill as an authorized check. The bill is drawn on pink paper of check size. It has the "Pay to" order printed and the signed authorization serves in place of the customer's signature. The bank pays the Treasurer, and the bill passes through and back to the customer along with his other checks. Entering the amount on his check book stub completes the transaction. The water department nor the customer has spent any postage. The customer has been saved a trip to the Water Office or the drawing and mailing of his check, or the embarrassment of forgetting to pay with the consequent loss of the 10 per cent discount allowed for prompt payment. Mr. Chamberlin says that the scheme really works in Rensselaer.

With Apologies!

Space does not allow more than a listing of the papers presented in "F.F.F."* Jordan's Symposium on Fire Protection—to wit: "Better Fire Protection for Smaller Communities"—Clarence Goldsmith, Assistant Chief Engr., Natl. Board Fire Underwriters, Chicago. "Cutting Fire Losses Through Systematic Inspections," R. E. Vernor, Mgr. Fire Prevention Dept., Western Agricultural Bureau, Chicago. "Valve Inspection and Maintenance"—A. J. Meyer, Indiana Inspection Bureau, Indianapolis. "Training for Efficient Fire Service"—Clem Smith, Chief State Fire Marshal, Indianapolis.

Other papers read: "My Job at the Contract Window"—Nellie Coleman, Water Works, Richmond, Ind. "Courtesy and Appreciation"—A. C. Shea, Indiana Bell Telephone Co., Indianapolis.

The meeting closed with an interesting demonstration of Television by Professors C. F. Harding and R. H. George of Purdue's Electrical Engineering Department.

*"Fire Fighting Frank" explained President Calvert, is what those who know him say that he is.—Ed.

CAPACITY OF CAST IRON MAIN SUSTAINED BY CHLORAMINE TREATMENT

By J. WALTER ACKERMAN*

Utica, N. Y.

J. W. Ackerman

THE Consolidated Water Company of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922 when the use had increased and the delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and on November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	Delivery—Before	Delivery—After	"C"—Before	"C"—After
		1199.9	Oct.,'22	Oct.,'22	Jun.,'22	Oct. 8,'22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar.,'24	May,'22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug.,'25	Oct.,'25		
Aug. 27, 1925	17	1220.4	10.5	13.9	106	142
		1222.7	Apr.,'27	June,'27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July,'29	Sept.,'29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov.,'30	Mar.,'31	Nov.,'30	Sept.,'31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May,'33	July,'33	Apr.,'33	July,'33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr.2,'34	Apr. 12,'34		
Apr. 8, 1934	10	1226.1	11.9	13.7	111	144

Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramines to the present time. On April 16, 1936, the last determination of the "C" value was 138.

The graph accompanying this article shows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

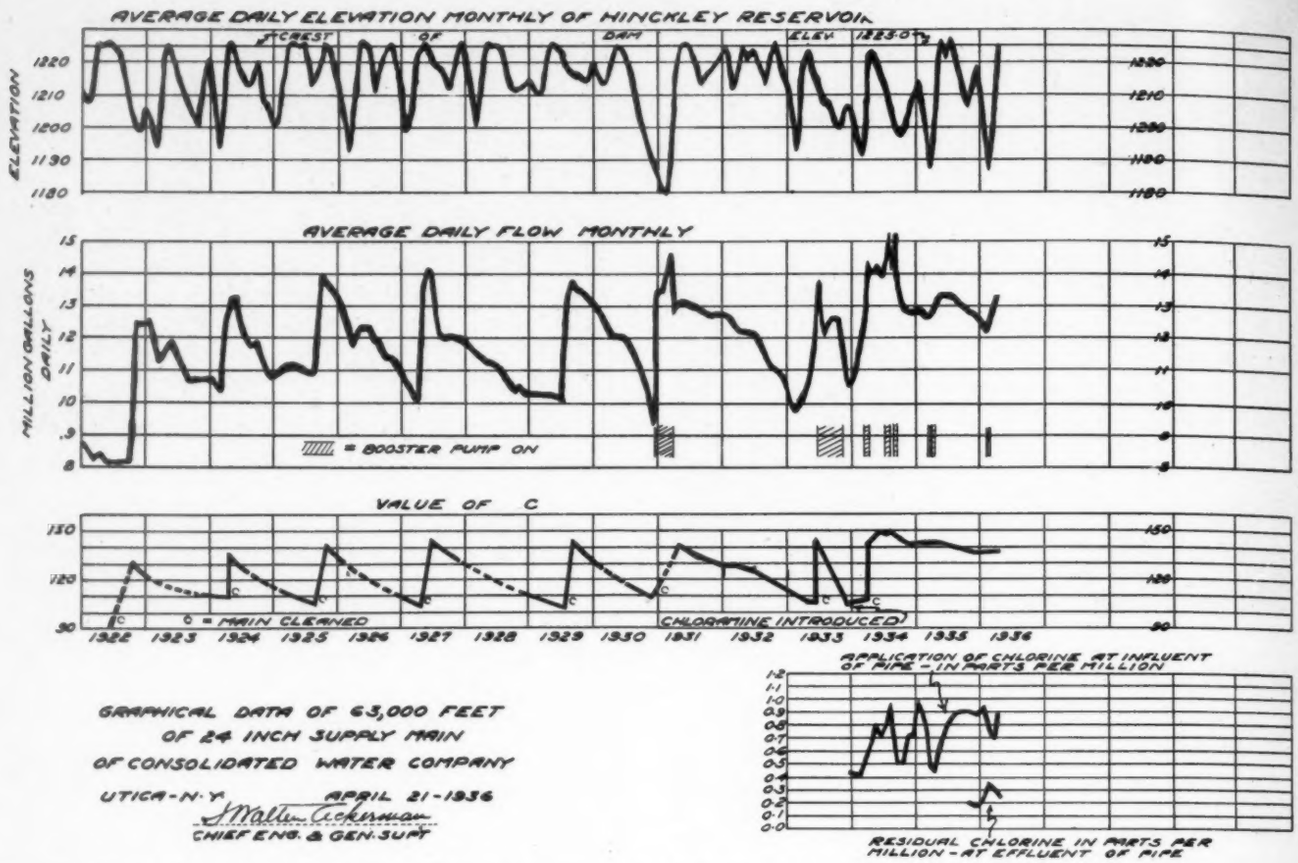
Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end gives the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by mamometer or pitot tube, and in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place. Therefore, there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as of course the different methods of computing the flow varies about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12 mile cast-iron supply main at Utica, N. Y., constitutes a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative rather than conclusive. Amongst his audience there were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with this in mind that WATER WORKS AND SEWERAGE asked Mr. Ackerman to present to its readers his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12 mile main.—Editor.

*Chief Engr. and Gen'l Supt., Consolidated Water Co., Utica, N. Y.


AVERAGE DAILY ELEVATION MONTHLY OF HINCKLEY RESERVOIR
ELEVATION
AVERAGE DAILY FLOW MONTHLY
MILLION GALLONS DAILY
= BOOSTER PUMP ON
VALUE OF C
C = MAIN CLEANED
CHLORAMINE INTRODUCED
1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936
APPLICATION OF CHLORINE AT INFLUENT OF PIPE - IN PARTS PER MILLION
RESIDUAL CHLORINE IN PARTS PER MILLION - AT EFFLUENT OF PIPE
GRAPHICAL DATA OF 63,000 FEET OF 24 INCH SUPPLY MAIN OF CONSOLIDATED WATER COMPANY
UTICA-N.Y. APRIL 21-1936
CHIEF ENG. & GEN. SUPT

Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the Carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with that for 1934-1936

12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less therefore than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 miles to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Those Who Will Be on the "Water-Works Special"

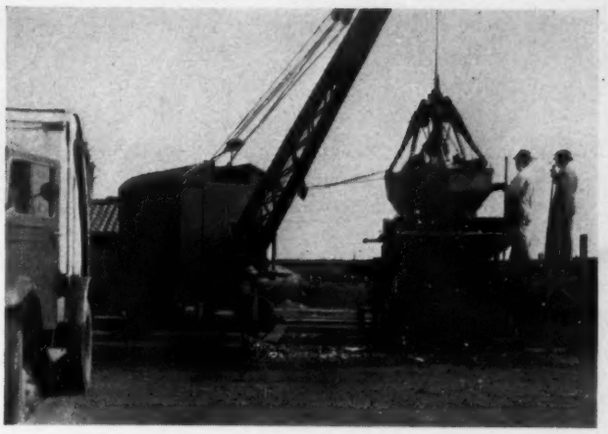
Leaving New York May 29th for Los Angeles
(Complete up to May 12th)

*Frank A. Barbour (Pres.), Boston, Mass.
Fred B. Nelson, New York City
*Clinton Inglee, New York City
*Sheppard T. Powell, Baltimore, Md.
*Wm. C. Sherwood, Boston, Mass.
Marian Chattery, New York City
*A. R. Murphee, St. Louis, Mo.
Wm. J. Orchard, Newark, N. J.
Sally and Jane Orchard, Newark, N. J.
Jane R. Hoimark, Newark, N. J.
Willard T. Chevalier, New York City
Karl M. Mann, New York City
Joseph Harper, New York City
Pat. E. Kelly, Arlington, Mass.
Wm. R. Conard, Burlington, N. J.
John W. Kay, Milford, Mass.
*W. C. Kirchoffer, Madison, Wis.
*Earle Talbot, Englewood, N. J.
John L. Ford (and Mother), Wabash, Ind.
Guy Northrop, New York City
Louis D. Blum, New York City
Alan D. Drake, Buffalo, N. Y.
*Frank E. Hale, Brooklyn, N. Y.
Mrs. Paul R. Staples, Brooklyn, N. Y.
*W. W. Brush, New York City
*Geo. W. Randall, Brooklyn, N. Y.
*Charles W. Mowry, Boston, Mass.
*George G. Schaut & Son, Philadelphia, Pa.
*George Schaut, Sr., Philadelphia, Pa.
*Abel Reynolds, Providence, R. I.
*A. V. Graf, St. Louis, Mo.
*Geo. H. Felix, Katherine Felix, Reading, Pa.
Mrs. H. Otto Lowe, Reading, Pa.
*Lewis V. Carpenter, New York City
*Charles Holbrook, New York City
*G. E. Boyd, New York City
Scotland G. Highland, Clarksburg, W. Va.
Charles F. Jost, New York City
L. A. Dickson, Pittsburgh, Pa.
James Kennon, Pittsburgh, Pa.
A. E. Hintz, Oshkosh, Wis.
W. R. LaDue, Columbus, Ohio
*Ed. Johnson, Pittsburgh, Pa.
*Percy S. Wilson, New York City
*J. E. Jagger, Birmingham, Ala.
*John S. Warde, New York City
Linn H. Enslow, New York City

*Those who are to be accompanied by their wives.

SEWAGE DISPOSAL PLANT OPERATIONS AT MILWAUKEE.—The entire cost of operation and maintenance of the disposal plant and intercepting and main system of Milwaukee, Wis., for 1935 was $960,000, with a credit of $300,000 from the sale of waste sludge, which is sold under the trade name of Milorgranite, leaving a net annual operating cost of $660,000, or about 90c per capita.

During the year the disposal plant treated an average og 85.61 million gallons of sewage per day; removed 97.4 per cent of the bacteria, and 91.5 per cent of the suspended solids.



(1) *Lifting Garbage to the Grinder Charging Platform*

THE EFFECT OF GROUND GARBAGE ON SEWAGE TREATMENT PLANT OPERATION

C. K. CALVERT[1] and S. L. TOLMAN[2]

AT Indianapolis, sewage from combined sewers is given preliminary treatment by a combination of fine rotary screens and short time sedimentation. These sedimentation (detritus) tanks are called rapid-settlers. The entire sewage flow passes through screen channels in each of which three 6 by 8 ft. screens and 1-16 by 2 inch slots, rotate. About two-thirds of the average daily flow passes through the screens and the other one-third, which is the concentrate carrying the solids rejected by the screens, flows from the screen channel through the rapid settlers where the detention period is about twenty minutes. The rapid settler effluent joins the screened sewage and the two constitute the clarified sewage which goes to the activated sludge plant for final treatment.

The activated sludge plant is of the spiral flow type. It is too small to treat all of the sewage in the conventional fashion. In order to relieve the river of its organic load, plain aeration treatment is given to all of the sewage. In practice, such treatment removes more of the biochemical oxygen demand than can be removed by treating only a part of the flow by the activated sludge process. Most of the time, however, one complete unit is used as an activated sludge plant for purposes of study. Waste sludge from the rapid settlers and from the activated sludge plant is pumped to open lagoons. After a lagoon is filled it is taken out of service until the sludge is sufficiently digested. Later the sludge is dug out of the lagoon with a clamshell and loaded directly into farmers' trucks.

The Indianapolis garbage plant is of the by-product reduction type in which the garbage is cooked and dried. The grease is then extracted with a solvent and the residue sold for fertilizer and feed. The liquor drained from the cookers contains a large amount of organic matter and it was believed that it would interfere with sewage disposal processes. However, a few years ago, laboratory experiments indicated that it did not disturb digestion of sludge and since that time it has been added to the sludge for disposal. The water used to condense the vapors driven off in drying the cooked garbage contains considerable volatile organic matter and this, added to the B. O. D. of the cooker water results in a total of about 70 lbs of B. O. D. per ton of green garbage processed. It was learned also, through laboratory studies, that well ground garbage added to the raw sewage, at the rate of 2 tons per M. G. seemed to aid in the sedimentation of sewage solids and increased the B. O. D. of the settled sewage only a nominal amount. Increasing the rate of garbage to 5 tons per M. G., however, produced less attractive results.

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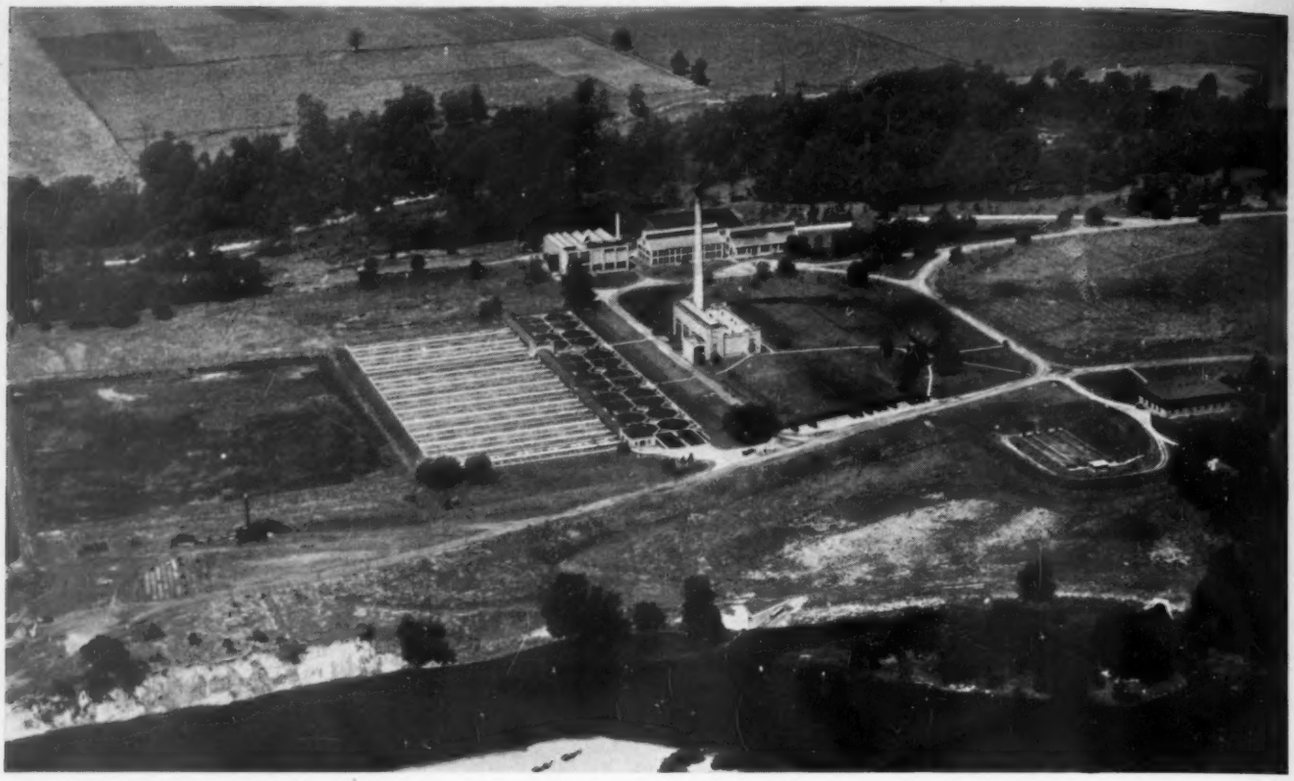
(2) *Feeding the Grinder*

A Full Scale Garbage Grinding Experiment

After eight years of service, the walls of the steam digesters at the garbage reduction plant were so reduced in thickness by corrosion that an explosion occurred, May 1, 1935. On account of the hazard involved, the Board decided not to operate the remaining units. On the basis of the laboratory experiments referred to above, it was decided to attempt to dispose of the garbage by grinding and adding it to the sewage. A grinding station was in operation two weeks after the acci-



Waste Disposal Plants of Indianapolis: Sewage Treatment Works and Power House in Center. Beyond the Power House Is the Garbage Reduction Plant. Right Foreground, the Detritus Tanks and Revolving Screen House. Left Foreground, One of the Sludge Lagoons and Screenings Incinerator. (Photo by Aero-Graphic Corp.)

dent which put the garbage reduction plant out of service.

The grinding station was located at the grit chambers through which the greater part of the sewage passes. A temporary receiving pit of 40 tons capacity was dug and lined with wood. The grinder selected was a Jeffrey ten ton per hour hammer mill, belt driven by a 50 h.p. motor. On account of the haste necessary, the grinder used was not of the type developed by the Jeffrey Company for this use. A centrifugal pump supplied 50 g.p.m. of raw sewage to the grinder to facilitate its operation and to carry the ground garbage into one channel of the grit chamber adjacent to it. A half-yard clamshell bucket was used to remove grit from the grit chamber channels, located so that it could lift garbage from the receiving pit to the charging platform Illustration 1). Three men fed the machine by pushing the garbage through a swinging door into the hopper over the grinder (Illustration 2). They also picked out tin cans, heavy bones and large pieces of metal, although this material was put through the machine for the first month of operation, after which it was picked out to conserve grit chamber storage space and protect the grinder, which was not equipped with a metal catcher. The picked material consisted of 3.1 lbs. of bones and 3.4 lbs. of metal per ton of green garbage.

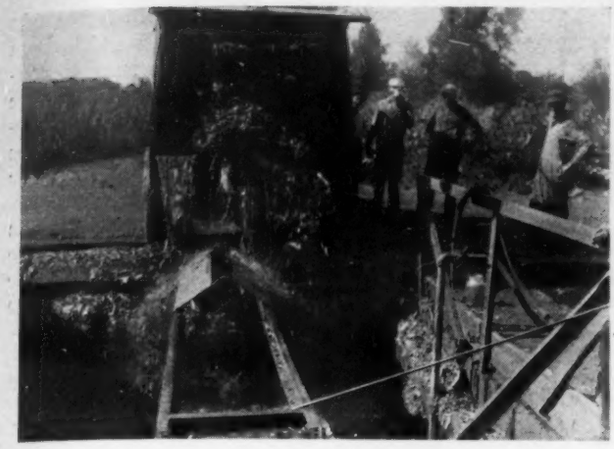
At the start of the operation, the bar openings, in the bottom of the grinder, through which the ground garbage passed, were ¾ inch, and this spacing was continued until the garbage tonnage fell off in the fall making it possible to reduce the spacing to ½, ⅜, and eventually ¼ inch. The finer grinding proved preferable because it reduced the amount of floating solids, improved the organic content of the grit and seems to promote rapid and more complete settling of solids in clarification, evidence of which appears later in graphs and tables.

Grit Composition

Indianapolis sewage grit is normally not particularly free from organic matter. It usually contains about 30 per cent volatiles at the influent end which may increase to 60 per cent at the effluent end of the chambers. The grit from garbage is difficult to evaluate. During the coarse grinding, it contained much organic matter and was offensive. It was removed once each week and covered on a dump. With fine grinding, the organic content was reduced as was also its offensiveness. A grit washer with suitable water velocity, produced a relatively inoffensive grit that could be disposed of as sewage grit usually is. Its ash content is lower than good sewage grit, the reason for which is shown in table 1, together with the general composition of the grit. This was determined by sorting a number of grit samples and weighing the various classifications. The figures do not include the hand picked bones and metal. Total grit (28 pc. water) from the green garbage was 38.2 lbs. per ton.

TABLE 1.
COMPOSITION OF DRY WASHED GARBAGE GRIT

Constituent	Per cent by Weight as Collected	Per cent of Original Constituent in ash after ignition
Organic Matter	6	20 to 40
Coffee	4	2 to 3
Nut Shells	4	Less than 1
Bone	35	65 to 72
Egg Shell	20	53 to 55
Glass and China	12	100
Sand and Cinders	4	40 to 50
Metal	15	100
Total	100	



(3) *Garbage Sampler in Use*

It is easily seen that the ash from garbage grit is less than that from sewage grit and that the ash content cannot be used as a measure of its freedom from organic matter that may cause odors. However, coffee grounds, nut shells, and bone may decompose under some conditions and garbage grit piles have heated in some cases.

At Indianapolis, grit production from sewage amounts to 11,340 lbs. per average day. At 31.7 lbs. of grit per ton of green garbage, it would constitute 23 p.c. of the sewage grit from the maximum year, 43 p.c. for the maximum week and 56 p.c. for the maximm day, based on an annual garbage production of 30,000 tons.

As has been stated, the floating matter was a problem during coarse grinding. The fine grinding, however, reduced it to a negligible amount—so small, in fact, that it was not possible to estimate the extent when examining the settling tank skimmings.

Garbage Sampling

An attempt was made to sample garbage by taking a shovel full from each truck load delivered to the receiving pit. Using all possible care, such a sample obviously did not represent the entire load. The collection trucks are equipped with draining devices, from which liquor is removed during collection, to permit the hauling of larger loads without spillage. All trucks are drained just before weighing but, even so, the lower part of the load is wetter than the top. A sampling device was made (Illustration No. 3), which was supported on the sides of the pit. A tub was suspended beneath a 7-in. slot to catch a section through the load as it was dumped. It is believed that the sample so collected represented the whole load very well. Ten tubs were filled in this way, kept covered and, at the close of the day, all of it was put through the Jeffrey grinder, without the addition of water. The material ground was sampled continuously, about a tub full being collected. The tub of ground material was sampled and examined for total and soluble solids. The remainder of it was put through a sausage mill, to reduce the size of the particles, sampled and examined for the items shown in table 2. This procedure was carried on from August 19 to December 14, during which time 74 samples were examined, total weight calculated for the tonnage ground, and these used in arriving at averages.

TABLE 2.

	Pounds per Ton of Green Garbage
Total Solids	350
Insoluble Suspended Solids after coarse grinding (from Jeffrey Grinder)	260
Homogenized*	192
Oxygen Consumed	153
Biochemical Oxygen Demand	152
Total Organic Nitrogen	7.59
Petroleum Ether Soluble	40.2

*In order to obtain an emulsion of garbage which could be measured for the various determinations, 50 gms. to 1 litre of water were put through the homogenizer used on sewage samples. (See illustration.)

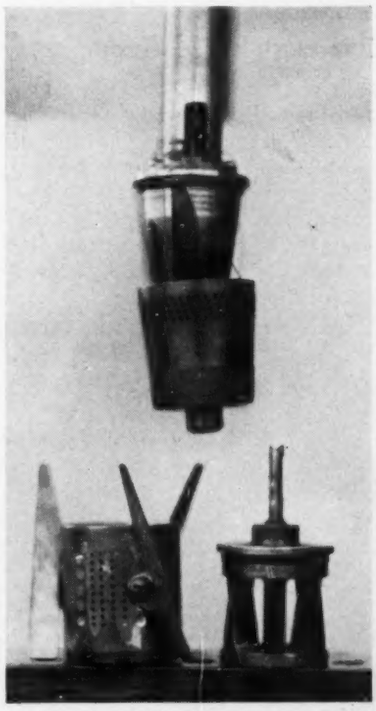
It should be noted that the sample was dried before making the T. O. N. (total organic nitrogen) determination which is believed to have resulted in low figures. Assuming 0.4 lbs. of garbage per capita (the highest annual figure in the Indianapolis records) the garbage B. O. D. per capita per day is calculated to be 0.03 lbs. This is 18 p.c. of the generally accepted sewage per capita equivalent and 11 p.c. of the Indianapolis figure, and for the maximum week this figure would be doubled.

Sewage Sampling

Throughout the life of the Indianapolis Sewage plant, 24-hour weighted composite samples of the clarified sewage, the final effluent and of all sludges have been examined daily in the laboratory. The same sampling and laboratory schedules were maintained during the garbage grinding.

In addition to the usual schedule samples were taken each day at 15 minute intervals, during the garbage grinding period, of the raw sewage before and after the addition of the garbage, of the raw sewage entering the plant from a sewer not receiving the garbage, and at a number of points in the clarification process.

Standard Methods of Analysis (A. P. H. A.) have been followed except in two particulars. All samples of raw and clarified sewage (but not final effluents) were homogenized before portions were measured for any determination. The homogenizer consists of a plug rotating at 3,600 r.p.m. inside a stationary shell. The plug is milled to draw the liquid in at the bottom, carry it upwards around the plug through a decreasing clearance, and force it out through 1-16 inch round holes at the top. The device is submerged during operation which prevents aeration of the sample. It was developed to reduce the size of the suspended solids in sewage samples and make them more uniform (Illustration 4). Gooch crucibles, for the determination of suspended solids have, for some years, been topped with about 1-16 in. of celite "HY-flo" to increase their effectiveness. In all other respects laboratory procedures were standard.



(4) *The Homogenizer. Original Device Shown Below. Upper Part of Picture Shows Final Development with Outer Casing Lowered to Show Construction of Rotating Element.*

TABLE 3.—SCREENED AND SETTLED SEWAGE COMPARED WITH CLARIFIED.

	Per Cent Found in Clarified Sewage
Suspended Solids	93.3
Total Solids	97.3
Oxygen Consumed	97.7
Biochemical Oxygen Demand	97.9
Total Organic Nitrogen	99.1
Petroleum Ether Soluble	97.2

TABLE 4.

	Per Cent Recovery in Sewage
Total Solids	89
Suspended Solids	91
Oxygen Consumed	70
Biochemical Oxygen Demand	115
Total Organic Nitrogen	117
Petroleum Ether Soluble	69

As evidence of the accuracy of sampling and laboratory work, the sum of the poundage of the various items determined separately in screened and in settled sewage checked with that in the clarified sewage (a combination of the two) as shown in table 3.

None of the samples in this comparison are of raw sewage which is harder to sample than clarified. No samples have been taken of raw sewage as routine until the garbage grinding experiment started. In the past, raw sewage figures have been obtained by adding the primary sludge to the clarified sewage. This method gives the raw sewage content directly on suspended solids, total organic nitrogen and petroleum ether soluble; and, indirectly on biochemical oxygen demand, assuming that the ammonia-B. O. D. ratio in clarified sewage obtains also in the primary sludge.

The 1934 average raw sewage is calculated to have contained (in p. p. m.) suspended solids 347, B. O. D. 271, total organic nitrogen 37.5, and petroleum ether soluble 43.4. This gives an idea of the kind of sewage to which the ground garbage was added.

Recovery of Garbage

The sewage was examined before and after the addition of the garbage, the difference being attributed to the latter. Raw sewage is very difficult to sample on account of the variation in the size of the particles. However, samples were taken at points of natural or induced turbulence. Table 4 shows the recovery found in this way for a six weeks' period on the basis of the garbage content as determined by direct examination, shown in table 2.

The solids figures are affected, perhaps, by imperfect mixing, and failure to take into account, sufficiently, the grit and floating material removed in the grit chamber which is located between the points at which the two sewage samples were taken. No explanation has been found to account for the great loss in oxygen consumed. Laboratory mixtures of garbage and sewage show no reduction in the sum of the two made separately. The B. O. D., however, is higher in mixtures than the sum of the two separately. The total organic nitrogen may be affected by the fact that, in the garbage, it was determined on a tried sample. The petroleum ether soluble may be affected by sampling. This because deep, rather than shallow, samples are taken and the nature of the material tends to bring it toward the surface.

Effects on Sewage and Treatment Due to Garbage Grinding

Graphs A, B, and C show the pounds increase per ton of green garbage, by weeks, of suspended solids, 5-day B.O.D., and oxygen consumed in raw and laboratory settled sewage and the tons of garbage added per M.G. of sewage when garbage was being ground. The graphs are rough and illustrate the difficulties in measuring and sampling the materials under study. Attention is called to the increase in raw sewage suspended solids during the latter part of the fall when fine grinding was practiced, and to the reduction (by settling) to a point *below* that in the sewage settled without garbage. Most noticeable was this effect during the greatest garbage concentration and again during fine grinding.

The oxygen consumed in the raw sewage increases sharply with the fine grinding but in the settling process the increase practically disappears.

The B.O.D. of the raw sewage, while being far from an even line, shows no such increase during fine grinding as was noted in the oxygen consumed. No adequate explanation has been found for the flat and low part of the settled sewage line for the period of heaviest grind. It may be seasonal or there may be a coagulating effect produced with the higher garbage concentration. It corresponds roughly with the lower, more uniform, part of the suspended solids line for the settled sewage. There is a slightly similar tendency in the oxygen consumed line, also.

The increases are considerable in the raw sewage, especially during the grinding period (Table 5). They are higher than would be found for an entire year because the lowest garbage tonnage comes in the winter. The striking thing is the very small increases remaining in the sewage after settling for 30 minutes. The high concentrations existing during the grinding period would seem to indicate that it might be advantageous to extend the grinding operation over a longer period of the day,

TABLE 5.—INCREASE DUE TO GARBAGE IN RAW AND LABORATORY SETTLED SEWAGE.

	Per cent increase in various constituents in raw sewage from addition of garbage if increases were considered as having been distributed over each day as follows:			Per cent increase in various constituents in supernatant from raw sewage settled 30 minutes if increases were considered as having been distributed over each day as follows:		
Constituents	24 hrs. per day	24 hrs. per day	During grinding period 8-12 hrs. per day	24 hrs. per day	24 hrs. per day	During grinding period 8-12 hrs. per day
Total Solids	5.	11.	11.	2.1	2.3	5.
Suspended Solids	13.	32.	27.	3.0	—1.5	6.3
Oxygen Consumed	18.	30.	41.	11.5	12.0	26.
Biochemical Oxygen Demand	15.	30.	34.	10.9	16.5	25.
Total Organic Nitrogen	5.	5.	10.	2.3	1.8	4.5
Petroleum Ether Soluble	15.	33.	34.	4.4	4.9	10.

NOTE.—Constituents of raw or settled sewage, without the addition of garbage, taken as 100 per cent. Period of tests: June 3 to Dec. 14, 1935. Maximum week of Loading: Sept. 16th to 21st.

although no evidence of overloading appeared in the activated sludge unit or in plain aeration process.

Primary Sludge Removal

Due to careless operation of the grit chamber, and also to coarse grinding of the garbage, a number of stoppages occurred in the waste sludge line from the primary settlers. Especially was this so during the peach season when quantities of seeds came in the garbage. It is believed that fine grinding and adequate grit removal would have eliminated all of the trouble. After fine grinding was started no sludge line stoppages occurred.

The quantity of sludge removed in clarification during the past nine years has averaged 983 lbs. (803 to 1125 lbs.) per m.g. For the year 1935, during which garbage was ground, the average was 1181 lbs., which is the highest yet experienced. A calculation of the removals, made in the ordinary way, by adding the weight of solids in primary sludge to that in the clarified sewage, shows the solids removal to have been 38 p.c. Assuming that the solids from the garbage were removed at the same rate as from sewage, and knowing the weight of insoluble garbage solids from the direct examination of it, it is calculated that the solids of sewage origin in primary sludge amounted to 1038 lbs. per m.g. This is not far from the average for past years. On this basis the primary sludge contained 86 p.c. sewage solids and 14 p.c. garbage solids. From the ash content of garbage and sludge, it was calculated that the ash of the primary sludge, containing garbage, should be 20.59 p.c. The actual average of the determinations made was 20.20 p.c.

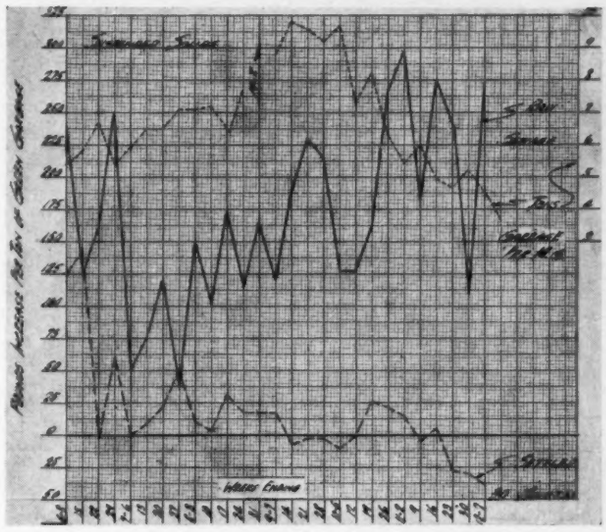
Ammonia—B.O.D. Ratio

In recent years, the clarified sewage at Indianapolis has contained from 6 to 7 lbs. of B.O.D. per pound of ammonia (NH_3). This is referred to as the ammonia-B.O.D. ratio. During the latter part of 1934, and continuing into April, 1935, the ratio was lower than usual. An increase started then and continued into early summer, remaining constant until fall. Since the ratio in garbage (about 16.5) is much higher than in sewage, the change in the ratio in clarified sewage might be attributed to the addition of garbage. The ratio in the sewage did not respond during the period of greatest garbage grind, and an examination of the individual clarified-sewage ammonia and B.O.D. figures shows that the ratio change is due to increases and decreases in them which could not be due to garbage. This matter is presented to illustrate the belief that rather frequent changes occur in sewage which are of greater magnitude than those caused by the additions of garbage.

Plain Aeration Process

The process of plain aeration consists simply of passing sewage through the aerators *without the return of sludge,* and collecting the flocculated solids in the usual secondary clarifiers. The air required is less than in most activated sludge plants and biologic action to some degree takes place. Greases, however, seem to be altered but little if any, very high concentrations being found in the sludge removed.

In Table 6 is compared the performance of the plain aeration process during garbage grinding with the same period of the previous year and the first part of the same year. The sewage of 1934 and 1935 was almost identical. Detention periods were similar but the rate of air used was less in 1935. The work done per unit of air was greater during garbage grinding in 1935, if compared with the same period of the previous year. The sewage during the first part of 1935 was materially weaker than during the summer when garbage grinding was carried on. Air was applied at a lower rate but it did less work per unit than when garbage was present. Table 6 reveals that the presence of the garbage did no damage to the operation of the bio-aeration process as practiced at Indianapolis. This may indicate that the presence of garbage increased the speed of purification but it is felt that evidence is insufficient to make such a statement at present.



Graph A—Effect of Ground Garbage in Increasing or Decreasing Suspended Solids

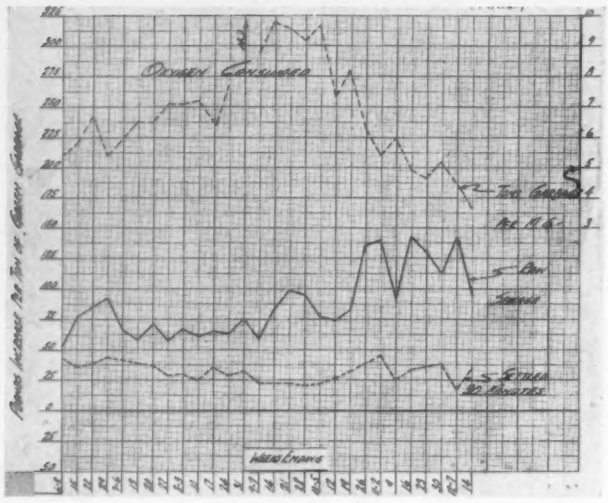
TABLE 6.—OPERATION OF PLAIN AERATION PLANT
(Bio-Aeration Without Sludge Return)

Period	Cu. Ft. of Air Per Gal. of Sewage	B.O.D. in P.P.M. To Aeration Tanks	B.O.D. in P.P.M. From Aeration Tanks	B.O.D. in P.P.M. Removed by Process	Thousand of Pounds B.O.D. removed per million cu. ft. of air
June-Dec. 1934	0.62	228	106	122	1.77
Jan.-May 1935	0.48	196	87	109	1.89
June-Dec. 1935	0.51*	231*	107*	124*	2.08*

*During garbage grinding period, June-Dec., 1935.

In past years, sludge from this process has been produced at the rate of 1254, 1375 and 1370 lbs. per m.g. These compare with the figure of 1390 lbs. for 1935. Solids were removed from the sewage treated to the extent of 71.1 p.c. in 1934 and 71.3 p.c. in 1935. On the basis of the same assumption as was applied to the primary sludge, it is calculated that the sewage solids removed amounted to 1227 lbs. per m.g., a slightly lower figure than for any previous year. The sludge produced is calculated to have been composed of 88 p.c. solids of sewage origin and 12 p.c. from garbage. The nature of the sludge was normal in respect to the nitrogen and petroleum ether soluble matter and slightly lower in ash. The ash figures indicate that the sludge contained about 18 p.c. garbage solids instead of 12 p.c. as calculated from the removals above.

On the basis of overall removals, it is calculated that the suspended solids in the effluent contained 13 p.c. of (8.1 ppm.) of material of garbage origin. By the same method it is found that 13 p.c. (15 ppm.) of the B.O.D.



Graph B—Effect of Ground Garbage in Increasing Oxygen Consumed (Permanganate Test)

in the plant effluent was of garbage origin. The B.O.D. removal in plain aeration was 55.3 p.c. before garbage grinding started and 54.5 p.c. during grinding. These are normal removals for this process.

Activated Sludge Process

In the past few years, the activated sludge process has been carried on in but one unit of the plant. This for the purpose of study and not economy.

In Table 7 is compared the performance of the activated sludge process during the garbage grinding period with the same period of the previous year, and also the first part of the same year. The figures for the two similar periods are almost identical except in aeration period, which was one hour longer for the garbage grinding season. The longer period is due in part to an interruption in the process, made to carry on a chemical precipitation experiment. Knowing the plant and the conditions under which it operated during the summer of 1935 it can be stated, with some assurance, that the aeration period could have been held at the same figure as during the previous summer. If the results had been calculated at the time the records were made, the rate of flow would have been stepped up and there is no reason to believe that the results of treatment would have been changed. As compared with the first part of the same year, when the sewage was weaker, the garbage grinding season shows slightly more work done per unit of air and a longer detention period. The data in this table does not indicate that the process was improved by the addition of garbage but there is also no indication that the garbage caused disruption of the activated sludge process.

Sludge production was a little higher, perhaps, than usual, but was almost normal.

The removals in sewage treatment while garbage was being ground have been calculated from the total weight of the various items. These figures are shown in Table 8.

The cost of grinding 17,256 tons of garbage during seven months, without interest and depreciation or supervision other than a foreman, has been that shown in Table 9.

TABLE 7.—OPERATION OF ACTIVATED SLUDGE PLANT

Period	Cu. Ft. of Air Per Gal. of Sewage	B.O.D. in P.P.M. To Aeration Tanks	B.O.D. in P.P.M. From Aeration Tanks	B.O.D. in P.P.M. Removed by Process	Thousand of Pounds B.O.D. removed per million cu. ft. of air
June-Dec. 1934	1.23	228	27	201	1.34
Jan.-May 1935	1.09	196	19	177	1.31
June-Dec. 1935	1.25*	231*	28*	203*	1.34*

*During grinding period, June-Dec., 1935. Compare with Table 6.

TABLE 8—PERCENTAGE REMOVALS

(Based on Raw Sewage Analyses)

	Clarification	Plain Aeration*	Activated Sludge
Total solids	11	14	20
Suspended solids	38	44	55
Oxygen consumed	20	40	61
Biochemical oxygen demand	15	45	76
Total organic nitrogen	11	18	40
Petroleum ether soluble	36	54	57

*May be considered as bio-flocculation without sludge return.

TABLE 9—ACTUAL COST OF GRINDING GARBAGE

	Total	Per Ton
Supplies	$ 33.97	$0.002
Power	1,087.36	.063
Labor	4,077.98	.236
Total	$5,199.31	$0.301

The power cost includes that used to drive the grinder, to operate the water pump (delivering sewage for flushing the grinder) and the clamshell which lifted the garbage from the pit to the feeding platform. The labor includes a foreman, an operator on the clamshell, and three men to feed the grinder. The men were allowed time to go a distance of 2 miles to and from the main plant and have showers after work. It is difficult to make an accurate estimate of the cost of construction and operation of a grinding station but the figures shown in Table 10 are liberal for the Indianapolis situation.

TABLE 10—ESTIMATED COST OF GRINDING STATION

		Total	Per Ton (30,000 tons per year)
Cost of building and equipment:			
Building and receiving pit	$11,000.00		
Two grinders, conveyors and grit washer	9,000.00		
Pumps, heating and misc. equipment	3,500.00		
Roads	500.00		
Truck	750.00		
Engineering and contingencies	2,500.00		
		$27,250.00	
Interest and depreciation		$ 3,091.25	$0.103
Operation:			
Power at 1.5c	$ 1,800.00		
Supplies and repairs	950.00		
Water and fuel	500.00		
Truck repair and fuel	200.00		
Labor—forman and 2 laborers	4,500.00		
		$ 7,950.00	.265
Annual total		$11,041.25	$0.368

TABLE 11—INCREASED SEWAGE PLANT COSTS BASED ON 30,000 TONS OF GREEN GARBAGE PER YEAR

	Total Per Year	Per Ton
Pumping volume of garbage added	$ 24.08	
Pumping of garbage solids in primary sludge	19.50	
Additional cost for air at activated sludge plant assuming garbage B. O. D. removed at same unit cost as Sewage B. O. D. including cost of sludge pumping	5,430.00	
Digestion pit operation and sludge removal	637.00	
Total	$6,110.68	$0.204

The total cost per ton of green garbage including increased sewage plant costs, interest, depreciation and operation of the grinding station is $0.572. The saving in haul figured at $0.20 per ton mile is $0.40, making a net cost per ton of green garbage of $0.172.

Increased costs at the sewage plant (Table 11) are on the basis of the addition of the loads imposed by the garbage solids and B.O.D. based on the unit costs in the past of removing the same items from sewage. This plan of calculating cost has been adopted even though no additional expenditure has been made at the sewage plant during the garbage grinding herewith reported. The digestion of the sludge with garbage present is more rapid than with it absent, but no credit is taken for that.

No increased interest and depreciation is shown in sewage plant since there is no evidence to indicate that a larger plant will be required.

The estimate of savings in haul of garbage is conservative, being materially under the estimate of the Superintendent of the Indianapolis collection department.

The cost of construction and operation of the old by-product reduction plant is shown in Table 12 for the years 1928 to 1934. The net cost of operating the by-product reduction plant, after taking credit for the by-products sold, is $3.38 per ton of green garbage and is to be compared with the net cost of $0.172 for grinding and disposal with the sewage as shown in Table 11.

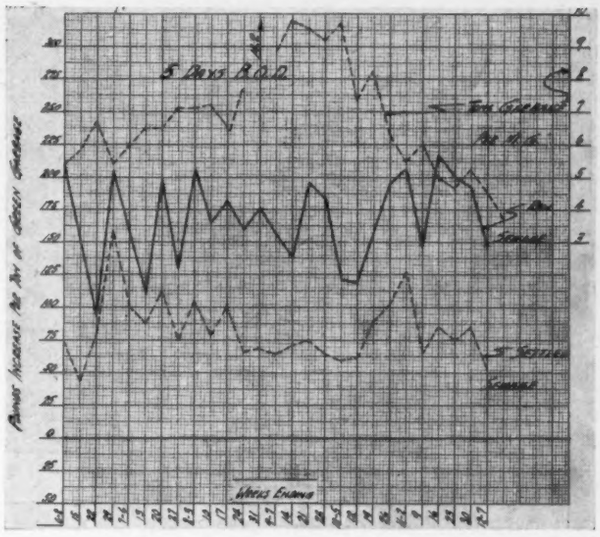
It is interesting to see how garbage grinding would have compared with incineration of garbage alone. The cost of a 200-ton per day incinerator would be approximately $125,000. Interest and depreciation at 7.25 p.c. based on a 30,000-ton year would be $0.30 per ton. The Chamber of Commerce of the United States in their report of April, 1931, entitled "Refuse Disposal in American Cities" gives the cost of operation of garbage incinerators in cities of over 250,000 at $1.55 per ton. The total operating cost per ton of green garbage including interest and depreciation is $1.85. This compares with the $0.172 cost per ton for grinding as a method of disposal.

While these differences quoted above apply to Indianapolis conditions, even had the sludge been digested in heated tanks and dried on sludge beds, rough computations show that grinding is still considerably less expensive than other methods of disposal. Further than this the digestion process yields methane gas values in operating power producing equipment for the air blowing process. It may be reasonably predicted that there is to be found an overall profit from garbage digestion at activated sludge plants where the additional gas production can be most profitably used in power production.

TABLE 12—COST OF OPERATION OF THE INDIANAPOLIS GARBAGE REDUCTION PLANT—1928-1934

(Total garbage reduced, 196,688 tons)

	Total	Per Ton
Interest and depreciation	$ 553,602.00	$2.82
Operation	702,501.00	3.57
Total	$1,256,103.00	$6.39
By-product receipts	592,062.00	3.01
Net cost	$ 664,041.00	$3.38



Graph C—Effect of Ground Garbage in Increasing 5-Day B.O.D.

Discussion

Ground garbage has been added to sewage by several cities in the past. Excepting possibly Lebanon, Penn. (and there none too successfully), no city has disposed of all of the collected garbage in this way. At Durham, N. C., garbage was ground and discharged to sewers feeding an activated sludge plant during the past summer with reported success. Concurrently there was a production of digester gas which rendered the aeration process self-supporting and even produced surplus power at times.

It appears on first thought that garbage should add a very heavy load to that which the sewage plant must treat, but every sewage plant always receives a considerable amount of waste from the domestic preparation of food. Besides juices, any solids fine enough to pass the sink strainer are flushed into the sewer. Observation of the screenings caught on the coarse racks shows conclusively that many people make a practice of disposing of rather large pieces of garbage by putting them through the toilet. The convenience and niceness of the household grinder recommends it and it will doubtless be used wherever the cost is not prohibitive. The present cost will prevent its general use. In any case, the additional load from this source need cause the sewage plant operator no alarm. However, even if it did interfere with plant operation, works would have to be designed and operated to handle it if the people insisted on using that method of disposing of their waste food. If possible, public plants must meet the demands made upon them.

In the peak of the garbage season, when vegetables and fruits are being canned, the garbage is quite heavy. It reached a rate of almost one pound per capita on one day last summer and averaged 0.8 lbs. during one week. While the peak garbage load is heavy, it comes at a season of the year when biologic activity is at its height and final treatment processes are better able to meet it.

The nature of the garbage has a large bearing on the feasibility of disposing of it with the sewage. If much rubbish is collected with it, grinding and disposal is made

more difficult. Indianapolis garbage due to household separation requirements is quite free from rubbish.

Obviously, ground garbage should not be added to the sewage if the disposal plant is unable to meet the conditions imposed by the sewage alone. The additional load, however, is not beyond the limit of variation which plants must be prepared to meet regularly.

The experiments carried on at Indianapolis and elsewhere show that garbage is digested rapidly with sewage solids. While no large scale controlled experiments have been conducted, it is believed that garbage will require no material increase in sludge digestion capacity since in balanced or controlled proportions it appears to speed up the digestion of the mixture. All of the sludge produced (primary, activated and plain aeration) was pumped to the open deep digestion pits which have been used since the plant was started. No garbage containing sludge has been removed as yet but digestion seems to have proceeded normally and there has been no change in odor.

While the evidence is conclusive that garbage may be digested at elevated temperatures, with sewage sludge without trouble and with a substantial increase in gas production based on organic matter, trucking the garbage to the digester results in the loss of such savings as would be realized by the water carriage of the ground garbage. After the removal of grit, garbage solids are not deposited in sewers to a greater extent than are sewage solids and any sewer which will carry sewage will carry properly ground garbage. The experience with the operation of the household grinders demonstrates the point that garbage solids are carried easily in sewers. While the garbage grinding operation at Baltimore included only the excess which could not be handled at the incinerator, the ground garbage in the sewer did not affect the functioning of the sprinkling filters.

Conclusion

After seven months' operation, the conclusion reached is that ground garbage offers no serious problem in sewage treatment and such disposition appears to be more economical than methods now in use.

From the standpoint of economics, it seems plain that such increase in sewage plant cost as may occur on account of the ground garbage, will leave a very nice margin in the difference between the cost of construction, maintenance and operation of a grinding station vs. the established types of garbage disposal installations and their operations.

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Waterworks Information Exchange of the Canadian Section A.W.W.A.

By A. E. BERRY*

Toronto, Ont.

A ready exchange of information on waterworks topics is one of the important features of membership in the American Waterworks Association. Various methods for facilitating this have been developed. The waterworks Journal, the technical press, and the annual conventions all play a most important part in this work. The Canadian Section of the Association has endeavored to go one step further and has initiated a plan known as the "Waterworks Information Exchange."

A. E. Berry

The development of this information exchange was brought about by the desire of the members to secure data on various details which otherwise might not be available. Usually when waterworks men wish information on any specific subject, they either search the literature or they communicate by letter with their fellow workers. The result has been the issue of many letters of inquiry and a duplication of effort, as well as no wide distribution of the resulting material. Now the secretary's office, in the Canadian Section, becomes the means by which such data is collected, and distribution is made to *all members* rather than the one individual seeking the data. Information of any kind can be collected, and the members of the Section make suggestions from time to time as to what material they would like.

Operation of the Exchange

The procedure followed is to prepare, and to distribute questionnaires from the Secretary's office. These are forwarded to all municipalities in Canada, where there are members. This list includes more than 100, and since they are members, they represent the most aggressive centers in the Dominion. For certain features, the data is collected for all municipalities in Canada, and a complete record is thus made available.

The distribution of the tabulated data is made on loose-leaf mimeograph paper. When the project was initiated, a loose-leaf folder was printed and distributed free of charge to every member. This contains a number of sections, each dealing with such subjects as, Water Purification; Finance, Accounting and Rates; Waterworks Operation; Section Activities, etc. In order to readily distinguish these, and to avoid confusion, different colors of paper are used. When the material is distributed in loose-leaf form, the appropriate color of the classified section is used, and the paper is perforated to fit the folder.

This system has been in use only for a limited time, but already the following material has been made available: sources and chemical constituents of water supplies; full details on fire protection charges; filtration and chlorination plants in all Canada; water rates, and related data; methods of operation, etc. Other material in the process of tabulation includes: details on waterworks intakes in all Canada; full details of filtration and chlorination plants in Canada; water storage capacities; freezing of water services; pumping equipment; rainfall data, and many other matters of interest to the waterworks official.

The reception of this service by the members of the Canadian Section has been most favorable and encouraging. It appears to be a worth-while effort and, as time goes on, it should become increasingly useful to the man who wishes to have tabulated material readily available at his desk.

*Secretary, Canadian Section, A. W. W. A.

(Note: Having learned of the operation of a Water Works Information Exchange by the Secretary's office, we considered it such a progressive and valuable service, that we requested Dr. Berry to give us this interesting account.—Ed.)

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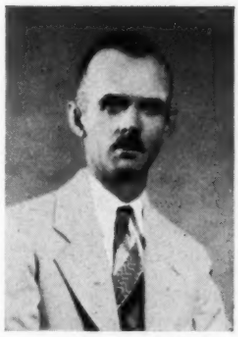
NEW YORK CITY CANNOT SET HYDRANT RATES.—The New York City charter provision that the Commissioner of Water Supply, Gas and Electricity shall have authority to fix rates for hydrant service for water supplied by private water companies was declared unconstitutional in a decision by Justice Francis Bergan of the Supreme Court. He ruled that the sole authority rested with the Public Service Commission under a law of 1931, and dismissed the city's camplaint.

Kahoka's New Chemical Sewage Treatment Plan—with Separate Sludge Digestion (Capacity 200,000 Gallons Per Day).

CHEMICAL PRECIPITATION SEWAGE TREATMENT PLANT AT KAHOKA, MO.

By **FRANK BEARD**

Consulting Engineer,
Kahoka, Missouri.



The Author

THE City of Kahoka, Missouri, has approximately 1500 population and is located in the agricultural section of the northeastern part of the state. There are no factories or industries other than those of the mercantile type.

In 1933, two bond issues were voted. One was in the amount of $25,000 for water works improvements and the other in the amount of $35,000 for a sewer system and sewage disposal plant. No engineer was employed prior to the first election and the above amounts were arrived at more on the basis of what could be voted rather than the amount needed for the improvement. Both projects were constructed under PWA.

Much preliminary investigation was done before the type of disposal plant was selected. Among the items considered were: the degre of purification necessary; the adaptability of the type to the plant site; the character of the sewage to be expected; the simplicity of operation, and the comparative costs of different types of plants from the standpoints of initial cost, operating costs and money available.

The stream which must receive the plant effluent has normally very little flow and during a dry season has practically none. Therefore it was necessary to provide complete treatment.

The general design was based upon a future population of 2,000 contributing 100 gallons per capita, per day, or, in other words, 200,000 gallons per day.

Selecting Type of Plant

The first type of plant to be considered was the Imhoff Trickling Filter type. This type had its advantages of simple operation, low operating costs and reasonably good final effluent. However, this type also had its disadvantages. Surveys showed barely sufficient head room through the plant site to permit a gravity flow. The heavier rains would cause the creek to flood the lower part of the filter bed and final settling basin. No local stone passed the tests for filter material, therefore it would be necessary to ship in filter material. Test borings showed that water-bearing sand would be encountered 12 feet below the ground surface, while for a gravity flow the bottom of the Imhoff tank must be thirty feet below this surface. Such conditions necessarily mean expensive construction.

A brief consideration was given to activated sludge and separate sludge digestion types of plants. These types for this particular site were found to have many of the above disadvantages, or others equally as serious.

The chemical precipitation type was then considered. A review of engineering magazines, published during the last five years, showed a surprisingly increasing trend toward this type of plant.

Chemical treatment was first tried in Paris in 1740 and has been in existence in some form or other ever since. The disadvantage of this type of plant in the past has been the cost of chemicals, rather than the initial cost or quality of effluent produced. Modern methods, however, have greatly reduced the cost of chemicals and modern equipment has developed the process of mixing the chemicals with the sewage, so that the amount of chemical required has been greatly reduced.

Preliminary experiments with a small flocculator indicated that ¾ grain of ferric chloride produced satis-

factory results. After flocculating for thirty minutes and settling for a period of one hour, samples of the effluent were caught in glass jars. These jars were left open for five days during hot summer temperatures and no odor or change was perceptible.

From these findings, together with results being obtained at the Shades Valley plant, of similar design, at Birmingham, Alabama, it was decided that the Kahoka sewage would lend itself readily to chemical treatment and the determining item in the final selection of the type plant to be constructed would be the relative initial cost of the Imhoff Trickling Filter Type as compared to the Chemical Precipitation Type Plant.

Therefore, alternate bids were requested on the two types. The low bid for the Imhoff type which consisted of a bar screen, Imhoff tank, dosing tank, trickling filter with rotary distributor, final settling basin and sludge drying bed, was $16,419.36, while the low bid for the complete Chemical Precipitation Type was $13,558.50, a difference of approximately $3,000.00.

Considering that for a part of the year, the flow of the creek receiving the effluent from the plant would be sufficient to permit the closing down of the chemical apparatus and also considering the possibility of using returned sludge, it was estimated that the cost of operating the chemical precipitation type plant would not exceed the cost of operating the Imhoff type by more than $120 per year. This would be 4 per cent interest upon the $3,000.00 difference in the initial cost of the two types. Due to the fact that the money available was not sufficient to build a plant and properly sewer the city, this $3,000.00 could very advantageously be used in extending the sewer system. Therefore, the contract was awarded for the Chemical Precipitation Type Plant.

Design of Plant

This plant consists of a bar screen, two control chambers, flash-mixer, flocculator, two clarifiers, pump house with sludge pump and chemical feed machine, control panel, etc., digester and sludge drying bed.

A general picture of the plant layout (see plan) is as follows: The incoming sewer main follows the north and south center line of the plant. The first unit is the bar screen. Next on this center line is the pump house. Next come the control chambers, quick-mix chamber and flocculator. These are constructed as more or less one unit. First is control chamber No. 1, then No. 2, then the quick-mix chamber; each is 3 feet wide and 3 feet long. The flocculator, which is 7 feet, 6 inches wide, and 18 feet long, is next on this center line. Clarifier No. 1 is to the left of the north end of the flocculator and clarifier No. 2 is to the right. The digester is located to the left, or west, of the plant center line, between the screen chamber and pump house, and the sludge drying bed is located west and north of the digester. Excepting the sludge drying bed, the entire plant covers a plot of only 80x100 feet.

A brief description of the different units is as follows:

Bar Screen: The bar screen is the ordinary one-inch bar screen, 4 feet long and 3 feet wide. It is manually cleaned. It is constructed with a by-pass arrangement so that in case the one-inch screen is allowed to become clogged, the sewage will by-pass this screen and go through a 3-inch screen 6 inches high. With an increase of 6 inches in the sewage level, it will go over the top of this screen. Thus, it is impossible for the screen chamber to clog to the extent of flooding the plant site.

Control Chambers: From the bar screen, the sewage flows to control chamber No. 1. Both control chambers are octagonal in shape and three feet across. Each is equipped with two steel stop gates and one wooden stop plank. Pipe lines leave control chamber No. 1 and run parallel to the sides of the flocculator to the collection chambers located at the north end of the flocculator. Other pipe lines leave control chamber No. 2 and run to the respective effluent channels of clarifiers No. 1 and 2. Each pipe opening is served by a steel stop gate, while the openings between chambers 1 and 2 and chamber 2 and the quick-mix chamber are equipped with wooden stop planks. By different setting of these stop gates and planks, the flow may be directed to either clarifier for primary settling or may be split between the two or the entire flow may be sent through the quick-mix and flocculator. There are, in fact, five different routings of the sewage flow through this plant. This subject will be discussed later.

Flash Mixer: The quick-mix chamber is composed of two compartments. Sewage enters from control chamber No. 2 into a compartment 15 inches wide, 3 feet long and 6 feet, 3 inches deep. The chemical is fed by means of a rubber hose in a vitrified clay conduit from the pump house through the wall of this compartment, where it mixes with the sewage at approximately 3 feet below the surface. The second compartment is 3 feet square and 5 feet deep. A turbo-mix (low lift pump) is fitted with the motor and gears over this compartment and the impeller at the bottom of the compartment. The drive mechanism of this unit is the dual cone type which can be adjusted to any speed desired. The sewage flows down through the first compartment above described and in this second compartment from the bottom through an 8-inch opening in a 30-inch steel dish casting equipped with deflecting blades similar to those of an impeller. The outlet from this second compartment is directly into the flocculator through a rectangular opening in the common wall between the mixing chamber and flocculator. This opening is 3 feet long and 15 inches deep, of which 9 inches is free board.

Flocculator: The flocculator is composed of a rectangular tank 18 feet long, 7 feet 6 inches wide, and 6 feet 3 inches deep, 9 inches of which is free board. It is equipped with two sets of chain driven paddles located at right angles to the direction of flow. These paddles are driven by a four speed motor. Wood baffles are constructed so as to prevent surface currents. Under full load of 200,000 gallons per day, the flocculation period is 40 minutes.

The sewage flows from the flocculator into the collection chamber at the end of the flocculator. This chamber is equipped with steel stop gates so arranged that the sewage may be directed through 8 inch cast iron pipes to either clarifier.

Clarifiers: The clarifiers are each 20 feet inside diameter with a side water depth of 5 feet 6 inches. They are each equipped with Door Sifeed clarifier equipment. At full plant load of 200,000 gallons per day these two clarifiers provide a total of three hours settling period. The effluent channel of each clarifier is provided with two effluent outlet chambers. One is on the side nearest the creek and the other is located conveniently for returning the effluent to control chamber No. 2. These chambers are

equipped with wooden stop plank. Eight inch vitrified clay pipe carries the effluent from each clarifier to the creek, and 8 inch vitrified clay pipe also runs from the other outlet chamber to control chamber No. 2.

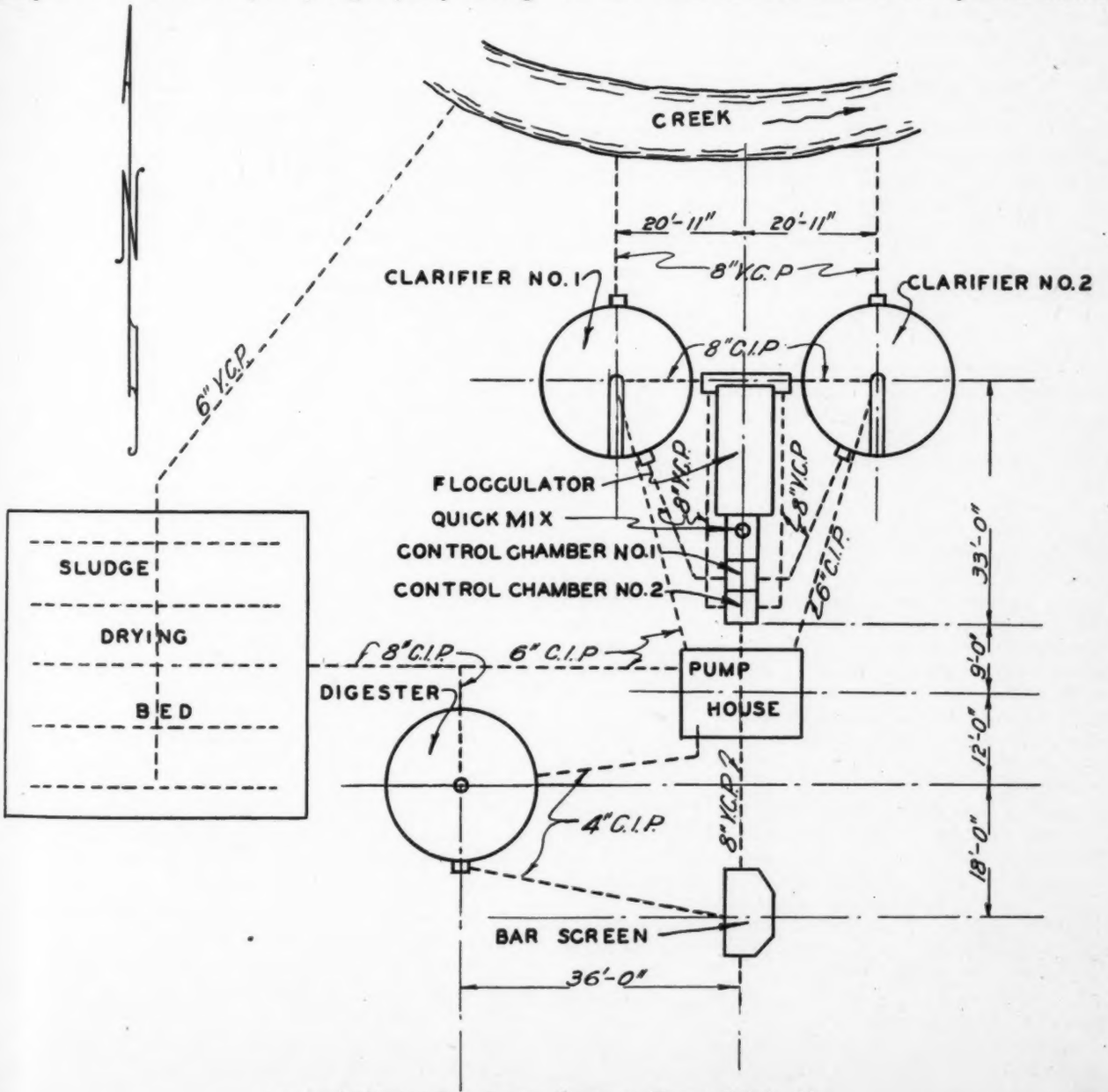
Digester: The digester, for construction purposes, was also designed 20 feet inside diameter. The same circular forms therefore served for both the clarifiers and digester. The side depth of the digester is 16 feet. It is equipped with concrete cover and gas collection equipment. No heating equipment was included in the initial construction. A waste burner for disposing of the gas has been installed. The digester has a capacity of 2½ cubic feet of sludge per capita.

The sludge drying bed is 40 feet by 40 feet square and of the usual under-drain construction.

Pump House: The pump house is 10 feet by 15 feet. In it are located the sludge pump, chemical feed apparatus and control panel board. The sludge pump is the Barnes simplex plunger pump having a capacity of 4500 gallons per hour. The pipe lines are so located that sludge may be pumped from either clarifier or from the digester for recirculating purposes.

Chemical Feed: The chemical feed machine is the Omega Pecision Solution Feeder, equipped with a 50 gallon tank. The chemical is carried from the feeder to the mixing chamber through a rubber hose protected between the building and the mixing chamber by a vitrified clay conduit buried below frost line. A wooden tank of approximately 200 gallons capacity has been provided for chemical solution storage purposes.

Automatic Control: The panel board was constructed by the superintendent of the Municipal Water and Light Plant. All control boxes are arranged on this board is as near possible to the respective positions of the units they operate. An automatic clock arrangement has been recently added to the control equipment which automatically turns on such units at such time as the operator desires



Layout of Chemical Type Sewage Treatment Plant at Kahoka, Mo.

and likewise turns them off after such period of operation as is desired. This plant does not have a full-time operator and such equipment greatly lessens the operator's work.

This concludes the description of the different units of the plant.

Flexible Design

This type plant is probably the most flexible known, from the standoint of operation. As has been stated elsewhere, the flow may be routed five different ways by different settings of the stop gates.

Normally there is very little flow in the creek receiving the effluent for dilution purposes. The preferred routing under this condition is from control chamber No. 1 to Clarifier No. 1, where, under full load of 200,000 gallons per day, it will receive a preliminary settling of one and one-half hours. From clarifier No. 1 the flow is back to control chamber No. 2, thence into the mixing chamber, where it receives the chemical dosage and is given a rapid mixing through the low turbo-mix lift pump into the flocculator. Here the slow moving paddle wheels build up a floc for forty minutes. From the collection chamber of the flocculator the sewage flows down through 8 inches cast iron pipes to the center of clarifier No. 2 and up through the Sifeed mechanism for one and one-half hours final settling. The effluent then flows to the creek.

During periods when the flow of the creek receiving the effluent will permit a lesser degree of treatment, the sewage may be routed through clarifier No. 1 for 1½ hours settling, then through control chamber No. 2 to clarifier No. 2 for another settling period of 1½ hours, and then into the creek. This routing omits the use of chemicals and flocculation.

It may be found more advisable under the above conditions (and also for chemical treatment at times) to divide the flow at control chamber No. 1 and route half to each clarifier, in which case each half would get 3 hours settling in the respective clarifiers before the effluent passed on to the creek. Under either of these last two routings the sewage receives only primary treatment and there must be sufficient flow in the creek receiving the effluent for adequate dilution.

It is also possible to route the entire flow through the quick-mix and flocculator and split the flow at the collection chamber at the far end of the flocculator. In this case the flow may or may not be dosed with chemicals. It seems more economical, however, to settle out the heavier solids before chemicals are added. Experiments have indicated that flocculation without the addition of a chemical assists somewhat in the settling of solids.

Another routing is reversing No. 1 and No. 2 clarifiers in the routing first described. That is, clarifier No. 2 is made a primary settling basin and clarifier No. 1 a secondary. The only difference in these clarifiers is in the speed of the rotation of the mechanism. The primary mechanism normally rotates at a speed of .1 r.p.m., while the secondary rotates at a speed of .066 r.p.m.

It is also possible for the purpose of inspection or repairs to cut out either clarifier entirely.

This disposal plant was accepted as complete September 23, 1935, and the sewer system was accepted as of October 1, 1935.

Performance

No laboratory records as to the performance of this plant are available. The city has not purchased testing equipment as yet, but intends to do so at once. As soon as the sewer system was accepted and turned into the plant on October 1, the operator began filling the digester and started experimental operation of the entire plant. The infiltration from the six miles of sewer system was a mere trickle.

It was found that the amount of chemical to form a satisfactory floc could be determined approximately by the appearance of the sewage as it left the mixing chamber. A trace of color at this point seems to be sufficient. More chemical than this turns the sewage black, but otherwise does not seem to affect the effluent in any way. Samples of the effluent have been taken at different times and set up in an Imhoff cone. No sample has shown sufficient settleable matter to be read.

The amount of chemical being used daily at the present time is only one-half gallon of 12½ per cent solution. Ferric chloride so far has been purchased in granular anhydrous form (practically pure $FeCl_3$), which dissolves at once in water, thus requiring no wooden trays or other arrangements to insure a uniform solution. The size of the solution storage tank is such that it is convenient to make up a 12½ per cent solution, therefore this is the solution used. Later, when the load on the plant increases, it is intended to pump a portion of the sludge from the secondary clarifier into a storage tank from which it will be returned to the mixing chamber during the low flow period at night. Experiments at other chemical precipitation plants indicate that sludge from sewage which has been dosed with ferric chloride retains a high percentage of available chemical and may be returned many times with beneficial results.

There has been no odor from the effluent or from the plant except that coming from the waste-gas burner on the digester. At the present time there is some gas forming in the digester, but not in sufficient quantity for continuous burning.

Automatic Operation Schedule

The operator's schedule at this preliminary period is as follows: the automatic control mechanism turns on all mechanisms each morning for a period of 1½ hours. The operator visits the plant each afternoon, rakes the screen, tests the control mechanism, and runs all mechanism for one-half hour. As the plant load increases, additional operating periods will be added, until finally continuous operation becomes necessary.

This plant is compact in arrangement, simple in operation, and comparatively low as to initial cost. It is believed that when sufficient connections are made to the sewer system to give a working load, the degree of purification obtained will be highly satisfactory. All mechanical equipment was furnished by the Dorr Company through the general contractor, F. W. Whitehead, Kahoka, Missouri. The final cost of the plant was $13,482.94.

Acknowledgment—The above paper was presented by the author before the Missouri Water and Sewage Works Association.

OPERATING KINKS IN SEWERAGE PRACTICE

By A. M. RAWN*

Los Angeles, Calif.

A. M. Rawn

SEWER cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. If given the opportunity, an intelligent operation and maintenance crew will probably develop that method which best suits the system upon which they are working. In time they will iron out difficulties incidental to their equipment and eventually may evolve something useful to their brethren elsewhere. In the hope that they have done the latter, the writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

Sewer Cleaning

Recently the writer directed the attention of readers of WATER WORKS AND SEWERAGE to the use of rubber beach balls for cleaning lines up to 30 inches in diameter.[1] Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the District forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

*Assistant Chief Engr., Los Angeles County Sanitation Districts, Los Angeles.
[The author is also President of the California Sewage Works Association.—Ed.]

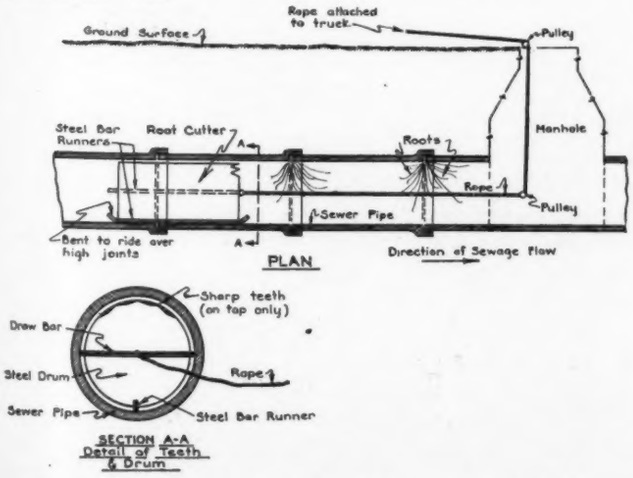


Fig. 2.—Root Cutter for Sewers of 12 to 36 in. Diameter.

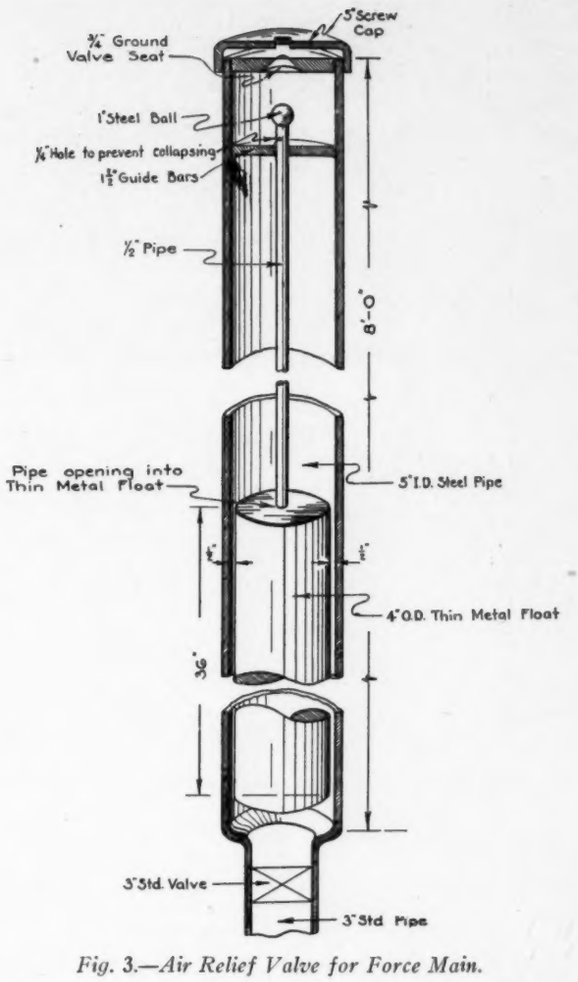


Fig. 3.—Air Relief Valve for Force Main.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic cleaning ball, described in the October 1935 issue of this magazine, the "hoe" moves easily over fixed obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the Districts' lines. None of them, however, has proven much more

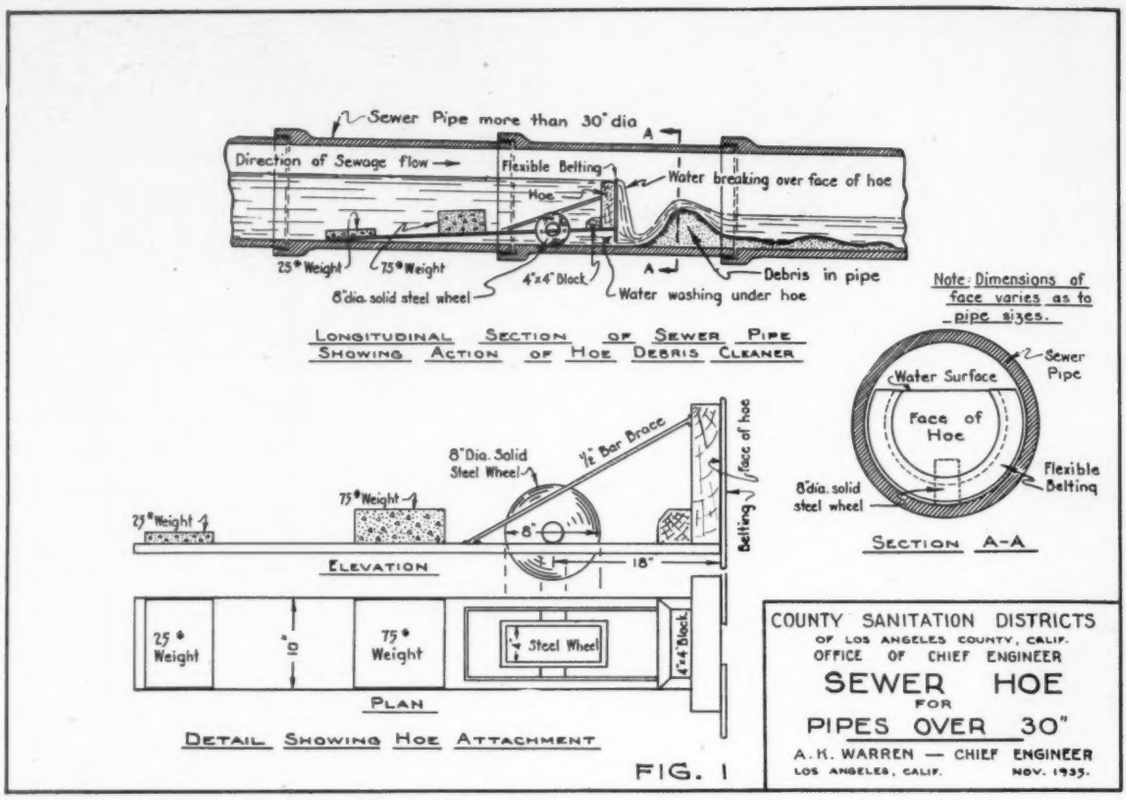


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 in. Diameter.

efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose at its point of entrance into the line, at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air-Relief Valve

Figure 3 illustrates a type of air relief valve used in the 3½ mile (36-inch diam.) effluent pump line leading from the Districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 feet from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched (Fig. 3) was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the

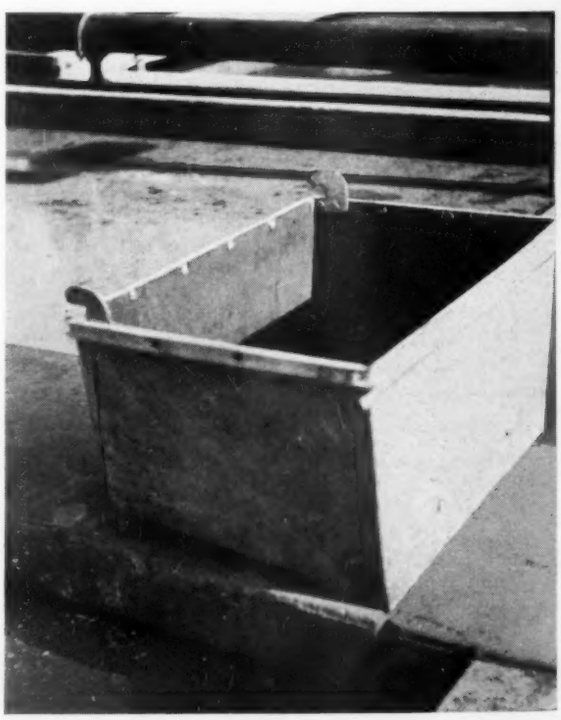


Fig. 4.—Containers Placed Next to Tank Ready for Skimmings.

pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the Districts' treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheel-barrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the re-accumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow shown in Fig. 4, et seq.

The container or pan may be made any convenient size. That shown in Fig. 4 holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use at the plant.

For transporting the pans to the incinerator the pneumatic tire wheel-barrow shown in Fig. 5 was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross

Fig. 5.—Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

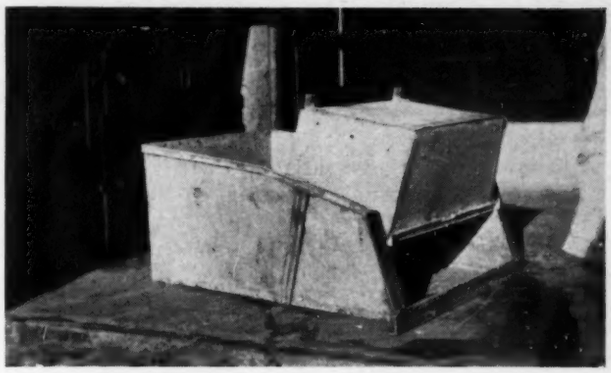


Fig. 6.—Storage Pan at Incinerator.

brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks attached to the barrow handles, and the load is securely engaged. The pneumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan (see Fig. 6) is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook in the manner shown.

The operator's hands do not come in contact with the skimmings or the containers at any time and the curse has been eliminated from an operation job that was once a filthy task. Moreover, the work is greatly expedited.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheel-barrow were all built in the plant shop by the plant operators.

[1] "Sewer Cleaning with Rubber Beach Balls." A. M. Rawn. WATER WORKS AND SEWERAGE, October 1935.

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Maryland-Delaware Association Adds District of Columbia

The tenth annual conference of the Maryland-Delaware Water and Sewerage Association was held May 14 and 15 at Frederick, Maryland. Rehoboth Beach, Delaware, was designated as the 1937 convention headquarters. The 132 registered at the meeting voted to open membership to engineers from the District of Columbia, and the constitution was revised to make this possible. New officers elected are: J. V. Cannen, Hagerstown, president; E. S. Hopkins, Baltimore, 1st vice-president; C. J. Bruce, Cumberland, 2nd vice-president; and A. W. Blohm, Asst. Engr. Md. State Health Dept., was re-elected secretary-treasurer.

Included in the papers given in the two-day technical program were those by E. S. Tisdale, Va. State Health Dept.; Earl Devendorf, New York Health Dept.; Morris Cohn, Consulting Engineer; Harry A. Faber, The Chlorine Institute; Dr. William Rudolfs, N. Y. Agr. Experiment Station; L. L. Lewis, Carrier Corp.; Dr. W. H. Schulze and C. H. Reynolds, Baltimore Health Dept.; and E. C. Maxwell, City Engineer, Frederick. An inspection trip to the local water filtration plant and PWA sewerage project concluded the program.

SECONDARY ELEMENTS FOR WATER WORKS AND SEWERAGE METERS

By L. D. CARLYON, M.E.
Bailey Meter Co., Cleveland, Ohio

METERS for measuring sewage, sewage sludges, air, and water, as encountered in sewage treatment plants and water works are comprised in general of two main parts known to meter manufacturers as the "primary" and "secondary" elements.

The primary element is that part which is installed in pipe line of the fluid to be measured and it may be either a Venturi tube, a flow-nozzle or a thin plate orifice. The function of the primary element is to provide a reduction in the transverse area of the pipe line, thereby causing an increase in the velocity of the fluid at this point with a corresponding localized drop in pressure. The result is a differential in pressure between the entrance and the throat of the Venturi tube or across the flow-nozzle and orifice. Since the differential pressure is proportional to the square of the fluid velocity, it may be used as an accurate index of the rate of flow.

The secondary element (more commonly known as a register by sanitary engineers) is actuated by the differential pressure and, through mechanical or electrical means, converts such into records or indications of the rate of flow. In addition a totalization of the weight or volume passing through the line is registered.

Although there are many types and makes of registers, they depend upon only a few basically different types of mechanisms designed to utilize the differential head. These form the basis for much of the following discussion concerning secondary elements as applied to various services.

Sewage and Sludge Meters

A sewage or sludge meter must be capable of continuous and accurate operation with a minimum of maintenance and attention. It must operate satisfactorily with a reasonable amount of foreign and solid matter existing in the system. The mechanism should be constructed of materials which will withstand the corrosive action of the gases present in a sewage treatment plant. The system employed should provide for venting of the gases formed as the liquid passes through the pipe so that it will not become gas-bound in the course of normal operation.

Because of the extensive use of the Venturi tube as a primary element, it is desirable to have the register designed so that its capacity can be changed by increasing the maximum differential head upon which it functions without altering the primary element or connecting lines, thereby eliminating expensive replacement of tubes.

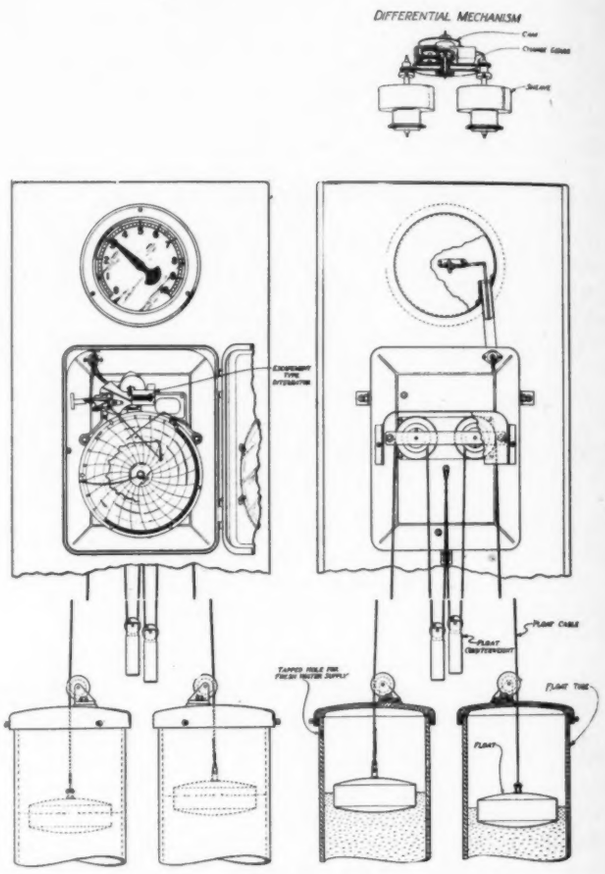

Fig. 1.—An example of the open float tube register for the measurement of sewage, sludge, and dirty water. (Courtesy of Bailey Meter Co.)

Registers for sewage, sludges or dirty water may be divided into two general classes of differential translating mechanisms; (1) the open float tube type, and (2) the pressure chamber type.

The Open Float Tube Register

The open float tube register is used only where the hydraulic gradient is relatively low and where changes in it are not severe.

This article sets forth a discussion of the fundamental types of meter registering and recording devices as applied to the measurement of the flow of sewage, sludge, air and water.

An article by the same author, which appeared in November, 1935, issue of "Water Works and Sewerage," presents a discussion of the "Primary Elements for Water Works and Sewerage Meters." In response to suggestions from many who have read the first article, the present discussion is presented by Mr. Carlyon as a sequel to his earlier article. Readers who have not seen the latter will find it reprinted in the Reference and Data Section, which constitutes a special feature of the 1936 Water Works Convention Issue of "Water Works and Sewerage."—Editor.

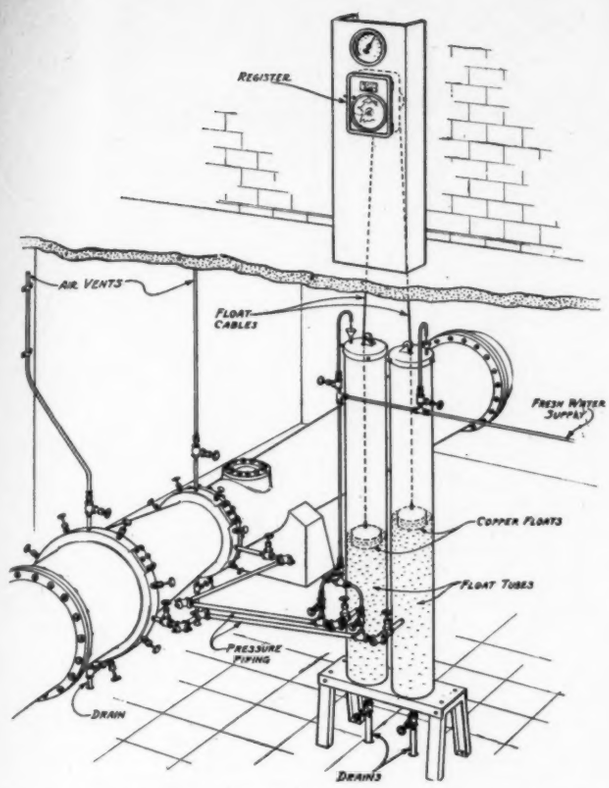

Fig. 2.—An approved method of installing the open float tube register for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

One example of the open float operated register is shown in Fig. 1 and a diagrammatic installation of this register, Fig. 2, illustrates its position relative to the float tubes, and the Venturi tube.

One float tube is connected to the inlet and the other to the throat of the Venturi tube by pressure piping so that the water level in each tube will rise to a height corresponding to the pressure existing in the Venturi tube at the point where the connection is made.

The rate of flow, represented by the difference in levels of the floats in the float tubes, is transmitted to the register by cables which are attached to sheaves as shown in Fig. 1. These cables operate the differential mechanism and square root cam which in turn transmit the rate of flow to the recording pen, the integrator and the indicator. A square root cam is employed to translate the differential into terms of flow so that the pen motion will be directly proportional to the rate of flow.

Another function of the differential gearing system is to automatically compensate for variations in line pressure or hydraulic gradient. This mechanism is designed so that if both floats rise or fall an equal amount there will be no change in the position of the operating cam. However, if there is a change in the difference between the levels in the float tubes, this change immediately operates the square root cam which in turn moves the recording pen to a new position, thereby registering the variation in rate of flow.

The maximum capacity of this float operated register can be altered by simply changing two sets of gears in the differential mechanism. This feature is provided to eliminate excessive costs for the replacement of the Venturi tube with modern equipment, wide variations in capacity can be obtained without removing the primary element from the line of disconnecting the meter in any way.

The register itself is mounted on the operating floor immediately above the float tubes. Cables are strung from the sheaves to the copper floats in the float tubes. This cable system is counterweighted as shown in Figure 1 so that there is an even tension on the float cables at all times. The float tube covers are provided with small pulleys to guide the copper floats in the center of the tubes undue friction in the mechanism.

A satisfactory method of installing the float operated register is represented by Fig. 2. The float tubes are usually made of 10-inch cast iron pipe and should be located directly below the register and as close to the Venturi tube as conditions will permit. A constant supply of fresh water is slowly introduced into the float tubes so that the water flows from the tubes out through the pressure piping to the Venturi tube thereby minimizing the accumulation of solid matter in the system. Provision is also made for flushing out the pressure piping with clean water under pressure, and also for cleaning the inside surface with a brush

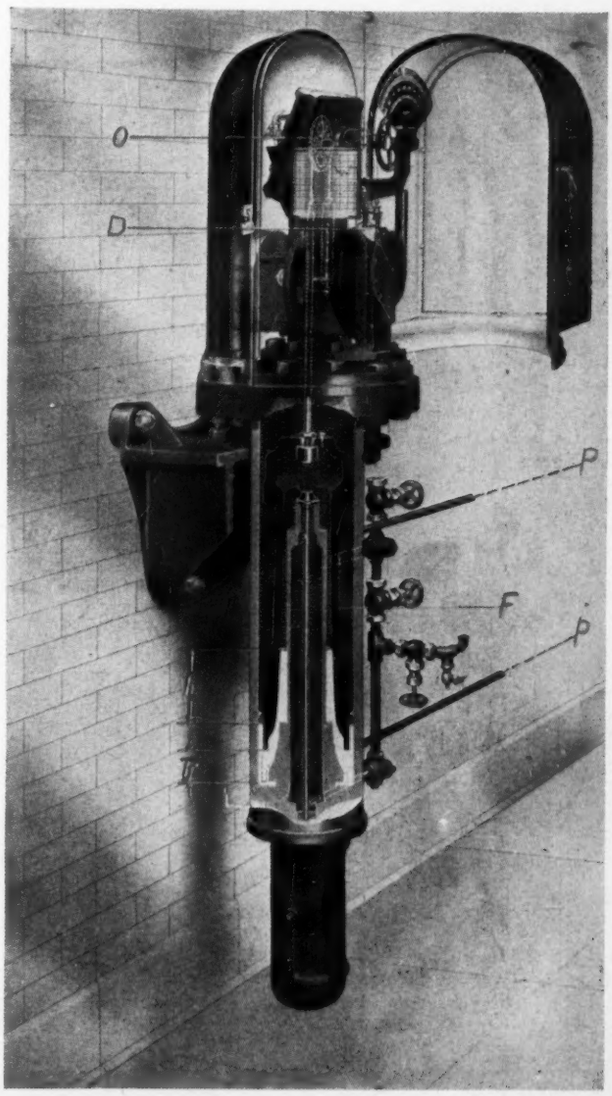

Fig. 3.—An example of the pressure chamber type of register using a mercury sealed bell. (Courtesy of Simplex Valve and Meter Co.)

or "ram" should such be necessary. The float tubes are fitted with shut-off valves and drain connections.

The piping connecting the Venturi tube with the float tubes is sloped (grade of ½-inch or more per foot) to prevent air or gas from becoming trapped in the piping and causing false levels to exist in the float tubes. The piping should be of 1-inch or larger copper or red brass pipe joined together with crosses at all changes of direction so that it may be rammed or brushed clean by removing the pipe plugs from each end of the run to be cleaned. Gate valves should be used on these lines instead of globe valves because they open to provide a free and unrestricted passage through the pressure piping, which is necessary to facilitate cleaning.

The fresh water supply piping may be readily constructed of copper tubing and compression fittings. Copper tubing of ½ inch diameter usually furnishes sufficient fresh water for the sight feeds.

Vents, leading to a point above the maximum hydraulic gradient, should be provided at the inlet and throat rings of the Venturi tube as shown in Fig. 2. To insure continuous venting, these vents should be left open at all times except when flushing the piezometer rings.

The "standard" arrangement of register and float tubes (Fig. 2) is not satisfactory in cases where the maximum hydraulic gradient rises above the register location. For installation under such conditions, the register may be mounted at an elevation *below* the float tubes and motion of the floats can be transferred to it by running the cables over a suitable arrangement of pulleys. Conditions of this kind can also be satisfactorily handled by the pressure chamber type of register and the sight feed system described in the following section.

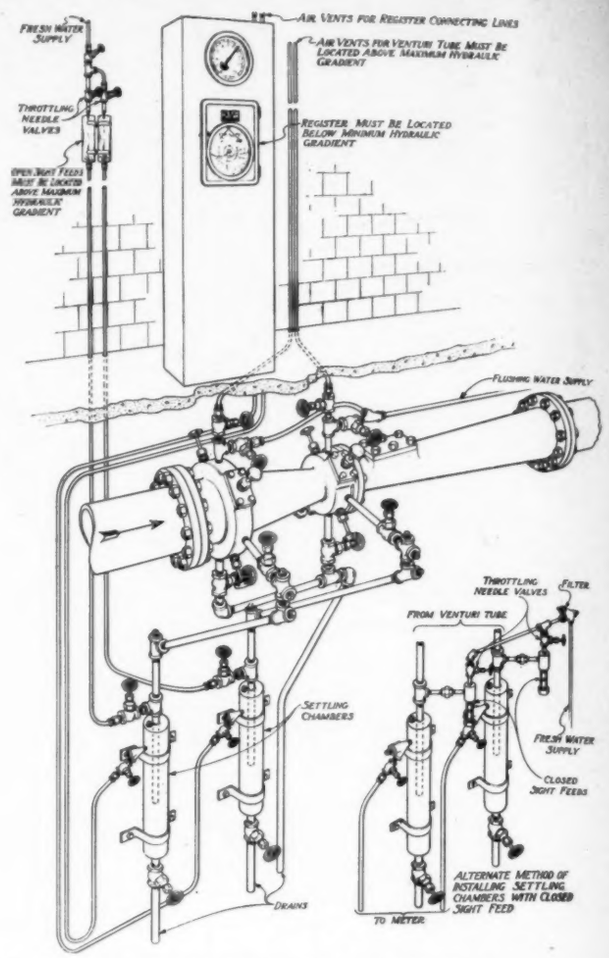
AIR VENTS FOR REGISTER CONNECTING LINES
FRESH WATER SUPPLY
AIR VENTS FOR VENTURI TUBE MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
THROTTLING NEEDLE VALVES
REGISTER MUST BE LOCATED BELOW MINIMUM HYDRAULIC GRADIENT
OPEN SIGHT FEEDS MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
FLUSHING WATER SUPPLY
THROTTLING NEEDLE VALVES
FILTER
FROM VENTURI TUBE
SETTLING CHAMBERS
FRESH WATER SUPPLY
CLOSED SIGHT FEEDS
ALTERNATE METHOD OF INSTALLING SETTLING CHAMBERS WITH CLOSED SIGHT FEED
DRAINS
TO METER

Fig. 5.—A recommended method of installing the pressure chamber register, whether bell or float type, for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

Pressure Chamber Register

Where line pressures are high, or when wide changes in the hydraulic gradient are to be encountered, the pressure chamber operated register should be used. With this type of meter, the pressure piping from the primary element is connected directly to the flow mechanism of the register which contains either a bell or a float.

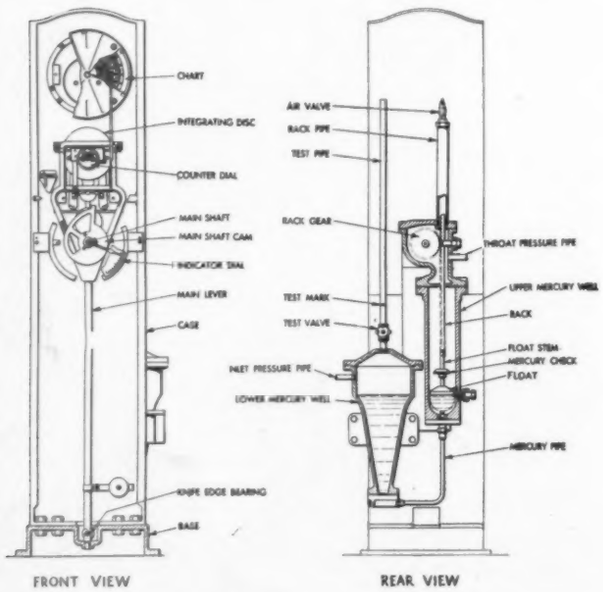

Fig. 4.—One example of the pressure chamber type of register using a float. (Courtesy of Builders Iron Foundry.)

One example of a pressure chamber register using a bell is shown in Fig. 3. The actuating mechanism, a hollow float of bell shape which is sealed in mercury, is subjected on the outside to the higher pressure from the approach side of the primary element and on the inside to the lower pressure. The float is shaped so that the resultant downward movement, from its position at zero differential head to the position of equilibrium, is directly proportional to the instantaneous rate of flow through the primary element.

Movement of the float is transmitted to a sheave, usually by a flexible cable provided with a counterweight and sheave clamp. The sheave is fixed to a shaft carried on pivot bearings. After passing through the stuffing box, the shaft further supports the flow pointer, the recording pen, and the integrating mechanism.

An example of the float type of pressure chamber register is illustrated in Fig. 4. The pressure connections from the primary element are connected to the two sides of a mercury U-tube, the higher pressure being connected to the tapered well, and the lower pressure to the well containing the float. As the rate of flow varies through the primary element, the mercury level in the U-tube will also vary, thus raising or lowering the float. This motion, through the rack and gear, provides the motive power for operating the indicating, recording, and integrating mechanisms.

The specially tapered well of the U-tube partially ex-

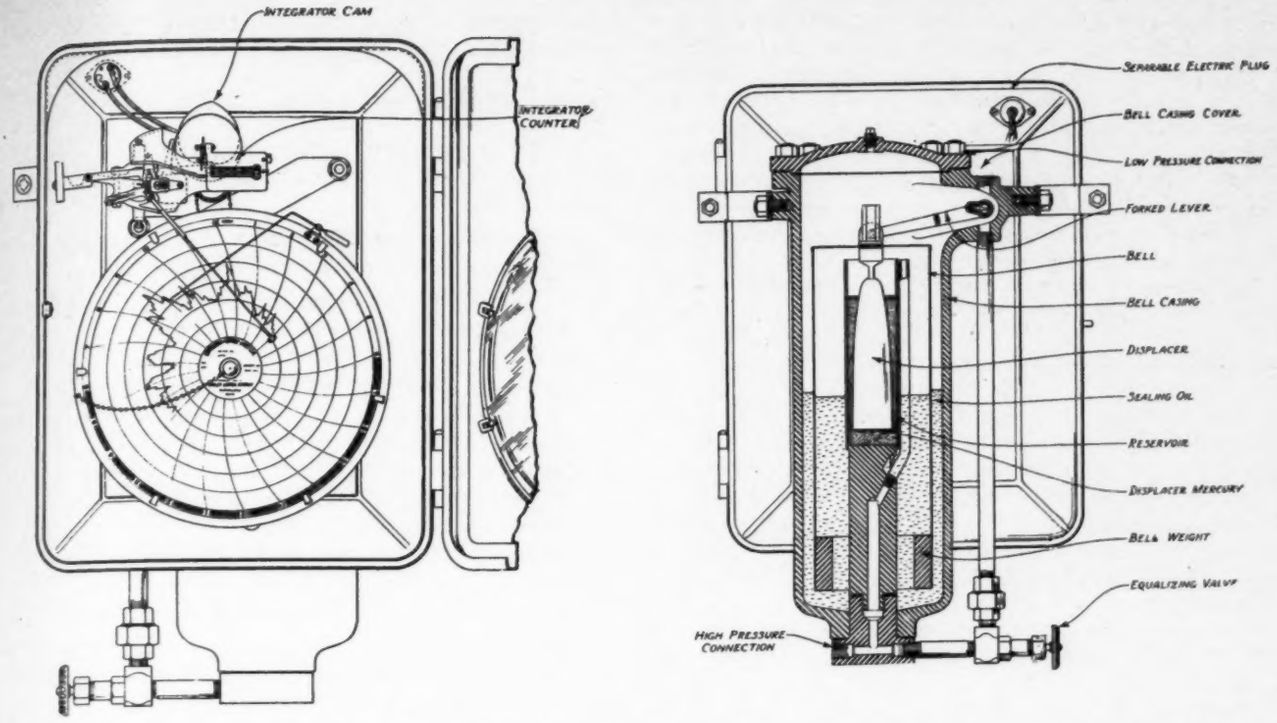

Fig. 6.—An example of the pressure chamber register using an oil sealed bell for measuring air. (Courtesy of Bailey Meter Co.)

tracts the square root of the differential, and the remainder of the function is converted by a shaped cam in the register so designed that actual motion of the recording pen and indicator becomes directly proportional to the rate of flow.

One method of installing the pressure chamber type of register in accordance with good engineering practice is represented by Fig. 5. Foreign matter is prevented from entering the register flow mechanism and connecting piping by the open sight feeds and the settling chambers. The sight feeds cause fresh water to flow from the settling chambers back through the pressure piping to the piezometer rings of the Venturi tube. This flow opposes the tendency of solid matter to work into the piezometer rings and pressure piping. The settling chambers, installed between the pressure piping and the copper tubing connecting lines to the register, collect and permit disposal of any solid matter which may work into the piping.

The pressure piping is of 1-inch or larger brass or copper. To facilitate cleaning, crosses are used for fittings, as shown in the illustration. From the settling chambers to the register, ½-inch copper tubing and fittings are suitable.

Open sight feeds are recommended in order to eliminate the possibility of water contamination by a direct cross-connection between the fresh water supply and the sewage system. If preferred, or if the maximum hydraulic gradient is too high to permit the convenient use of open sight feeds, closed sight feeds (see Fig. 5) can be used provided that the water supply to which they are connected is wholly independent of the city water. In some cases, an intermittent type of flushing system is used which utilizes city water. This however, requires the attention of an operator to establish and maintain the cross-connection and disconnect it when manual attention ceases. A flushing connection to the inlet and throat rings of the Venturi tube is also recommended.

When it is necessary to measure the flow through a line in which the hydraulic gradient varies over a wide range, and at the same time to locate the register above the minimum hydraulic gradient, the flow mechanism may be detached from the register and mounted at a lower elevation than the registering instruments. In this case, the movement of the flow mechanism is transmitted to the indicating, recording, and integrating devices by means of flexible cables.

Air Meters

For the measurement of air for aeration in the activated sludge type of sewage treatment plant, or mixing and partial aeration in chemical treatment, the translating mechanism of the register must of necessity function with a small differential head inasmuch as the static pressure of the air itself is low. Under these conditions the pressure chamber type of register is applied, but the sealing fluid usually is oil instead of mercury.

One type of meter used with air is represented in Fig. 6. The differential pressure is applied across the oil sealed bell to which is attached a specially shaped displacer which changes its immersion in mercury as the bell rises and falls with changes in differential pressures. The large size of the oil sealed bell permits operation on very low differentials, yet retaining ample power for the operation of the registering devices. The shaped displacer is so designed that the vertical motion of the bell becomes directly proportional to the rate of flow.

Installation of air meters is a relatively simple task since ½-inch copper tubing with compression fittings, or brass pipe and fittings, may be connected from the primary element directly to the pressure chamber of the register. Settling chambers are not necessary.

Water Meters

For the measurement of clear water the pressure chamber register as described for sewage measurement

is recommended. These meters are in service in the water works field on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water, and wash water and rates of filtration.

The installation of the register when applied to clean water is as simple as that of an air meter. Direct connections from primary element to pressure chamber may be made with ½-inch copper tubing or brass pipe. Settling chambers are not usually necessary, nor are the sight feed supply systems.

Register Instruments

The register instruments contain relatively simple mechanical or electrical devices which react in accordance with the movements of the flow mechanism to provide indications, chart records, and an integration.

It is advantageous if these instruments are designed so that additional equipment can be easily installed in them at any time for commanding the operation of auxiliary registers, signal devices, and controllers. This feature simplifies expansion of the services rendered by the main register such as operation of remote registers, totalization of flow through two or more influent lines to continuously indicate the capacity at which the plant is functioning. Likewise, for the automatic control by flow or the ratio of quantity of sludge returned to the aeration tanks.

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"NEW" METERS FROM OLD

La Verne Trentlage

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O. K." on the test bench. The procedure produces results in terms of more satisfied users created through improved confidence in that unit of the water supply business which is the factor of greatest contention between dissatisfied customers and the water utility.

Mr. La Verne Trentlage, up and coming young Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

In a paper presented recently before the Illinois Section of A.W.W.A., Mr. Trentlage described the work of the Meter Division and the method developed at Elgin, with the assistance of the General Chemical Company, for turning out reconditioned meters as accurate as they look after receiving the brightening treatment of the case and parts, which follows.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company. After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

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"Owed" to Chlorine

To rid our drink of potent germs,
To bring Typhosus to our terms,
To rout the dreaded clear-well worms,
We Chlorinate.

When tastes and odors we abate,
Or algae growths eliminate,
The first thing—we ammoniate,
Then Chlorinate.

When citizens at Mayors glare,
While sewage fragrance fills the air,
'Cause H_2S is hidden there,
We Chlorinate.

To beautify the creek's ravine,
And fungi from the bottom clean,
To make effluents more pristine,
We Chlorinate.

To halt B. Coli's fearful blight,
Or make stale sewage smell all right,
To bleach the baby's diapers white,
We Chlorinate.

Oh Chlorine! Praise be to thy name
And with it everlasting fame,
What *would* we come to in this game,
If we could not
CHLORINATE!

—W. Homer Wisely, Springfield, Ill.

Tampa's Modern Purification Plant. Moorish Architecture Fitting to Its Setting of Tropical Beauty

FLORIDA SECTION OF A. W. W. A. REVIEWS TEN YEARS OF ACCOMPLISHMENT*

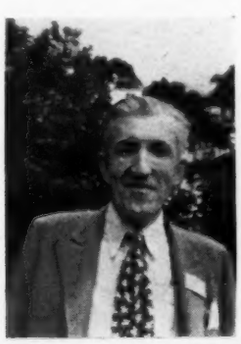
RETURNING for its tenth anniversary to Tampa, the city of its founding, the Florida Section of the American Water Works Association incorporated the fifth short course for plant operators at its meeting, March 31-April 1 and 2. In a technical program for, whose excellence, Dr. A. P. Black, Chairman of the Short Course Faculty, and J. R. Hoy, Secretary of the section, were principally responsible, papers of pertinent interest were presented. The local convention committee, headed by Joe Lyles, ably provided for the lighter moments of the meeting.

The Section members, the City and State, cooperated in making the 10th Anniversary meeting a real success. More than 110 registered for the sessions. The City of Tampa provided a barbecue supper in the tropical surroundings of the Tampa Purification Plant, and the three days of unfailing Florida sunshine contributed to the enthusiasm. For the afternoon of the first day, the attraction was a conducted tour through the Tampa plant, where J. E. Lyles, Superintendent, gave a paper on the methods of treatment employed, and demonstrated the viewpoint of the chemical engineer when applied to water treatment. Unique in its use of CO_2 made from stack gas and of sulfurous acid, prepared from the burning of sulfur, this plant exemplifies the most efficient use of modern knowledge of chemical application. Considerable interest was expressed in unusual lime, alum, and activated carbon feeding devices, as well as the efficiency of chloramine treatment.

In the evening of the second day of the meeting, the Annual Banquet and Dance, held at El Pasaje, Ybor City, contributed Cuban atmosphere. Dr. Black presided as toastmaster, entertainers offered native songs and dances, and guests supplied impromptu speeches. Dancing completed the evening. On the closing day, a choice of trips were offered—to the new treatment plant of the Pinellas Water Company, 15 miles from Tampa, or a conducted tour of a local cement plant, cigar factory, and brewery.

Attending the meeting was E. L. "Florida" Filby, of Black and Veatch, Engrs., who, as Chief Engineer of Florida's Health Department, was an organizer of the Section, and served as its live-wire Secretary until he left the state.

Keith R. Chinn, West Palm Beach Water Co., Chairman of the Section.



Prof. A. P. Black, Univ. of Florida. Does a bang-up job with his Short School

New Officers

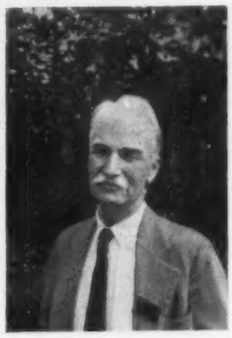
At the first session, members and guests were welcomed by Tampa's Mayor, R. L. Chancy, and J. S. Long, Supt. of Water. Beekman C. Little, Secretary of the National Association, congratulated the Florida Section and its officers on progress during its ten years of existence. He discussed the accomplishments in short school and operator licensing under the association committee.

At the business meeting during the final sessions, the new auditing committee reported on finances, and the resolutions committee submitted a resolution to the University of Florida, requesting that they make the short course operators' school a yearly institution. Officers elected for the coming year are:

Chairman—Keith R. Chinn, Chemist, West Palm Beach Water Company.

*This report has been made possible through the courtesy of Harry A. Faber, Asst. Engr. of The Chlorine Institute, who did a bit of pinch-hitting for Ye Ed.!—L. H. E.

E. L. Filby, Black & Veatch, Engrs., Kansas City, Mo. Organizer and former Secretary of the Section.



F. W. Lane, Supt., Water, St. Petersburg, Fla. An organizer of the Florida Section

Vice-Chairman—Donald S. Wallace, U. S. Geological Survey, Ocala.

Secretary-Treasurer—J. R. Hoy, Wallace & Tiernan Co., Jacksonville.

Trustees—G. F. Catlett, Chief San. Engr., State Bd. of Health, Jacksonville, and R. G. Ridgley, Manager, Pinellas Water Co., St. Petersburg.

Technical Sessions

(Acting Chairman, Keith R. Chinn, Presiding)

"Problems in Design of Distribution Systems," T. M. LOWE, Assoc. Prof., Civil Engineering, Univ. of Florida.

Comparing the theory with the practice of distribution system design, Mr. Lowe regretted that ordinarily the engineer must do a patchwork job, as he cannot anticipate the direction and rate of growth. Plotting of population curves almost invariably leads to an overestimate. Charts were exhibited to illustrate the layout of various types of distribution systems in use, these including the circle, tree, and grid types. Other charts showed graphically the influence of pumps and storage tanks on pressure regulation, and head loss in various sizes of pipes. In small towns, he pointed out, design must be based primarily on plans required for fire-fighting purposes.

Discussing Prof. Louis' paper in a very practical manner, W. N. Jones, Supt. of Dist., Tampa Water Dept., pointed out that the distribution system is an unseen unit of the department, expected to function upwards to 100 years. Giving recent cost figures, he showed their 14 m.g.d. system, to be divided as follows: Pumping, $250,000; purification, $650,000; and distribution, $3,000,000. They have 200 miles of cast iron mains, varying from 2 to 30 inches in diameter. Before introducing proper chemical correction of the water, pipe incrustation was an important problem—the original "C" value decreasing rapidly from 100 to 40. Now external corrosion is the main difficulty, pitting and dezincification being common because of the salt marshes, whereas electrolysis is seldom encountered. Contraction and expansion, due to heating (since their pipe is laid near the surface), must be taken up in the joints. Mr. Jones said that it was important that distribution systems seldom were put in charge of a specialized man, as were purification systems.

"Phases of Fire Protection of Interest to Water Works Men." L. C. SLEDGE, Eng. Dept., Southeastern Underwriters' Assn., Atlanta, Ga.

Stressing the importance of preparing and preserving accurate records of pipe-laying and valve locations, Mr. Sledge said the type of pipe and fittings best adapted to a given installation should be decided on the basis of performance of those already installed. Because of the ultimate detrimental effect on pumps, he pointed out that the forcing of pressures at times of fire is undesirable. "Off peak" pumping is bad procedure, since pressure decreases through the day and an adequate stored supply may not be constantly available. The all-important factor was the "residual pressure," which may be defined as that remaining when water is being used at periods of maximum consumption.

Because of the anticipated effect of the proposed Florida ship canal on conservation of natural resources and on agriculture, a symposium on this subject, not only aroused acute interest, but resulted in lively banter.

Predicting, **"The Effects of the Cross Florida Ship Canal,"** SIDNEY W. PAIGE, Senior Geologist, U. S. Engineer Office, Ocala, reported on a comprehensive study of conditions extending over a five-year period. Basing his opinion on the fact that the water table in the locality of the citrus groves and agricultural areas is now hundreds of feet below the surface, Mr. Paige pointed out that these sections would not be damaged. While some shallow farm wells in the vicinity of the canal will require deepening, the supplies of the larger cities will be entirely unaffected. Malcolm Pirnie, Consulting Engineer, New York City, added considerable geological data in confirmation of the opinion presented.

State Geologist, Herman Gunter, of Tallahassee, said that he would prefer to see a series of test wells drilled from high levels to that of the canal to more adequately disclose conditions which might be expected. In his opinion, the canal has a potential danger in lowering the main water tables.

Mechanics of Mixing and Settling

Citing improvements in recent years, both in mechanical equipment and in basin design, J. M. KAHN, International Filter Co., Atlanta, Ga., presented a thorough survey of such trends in his paper, **"The Mechanics of Mixing and Settling in Water Treatment."** The difference in physical properties of alum floc and calcium carbonate precipitate is now more generally appreciated, mixing and coagulating operations are generally separate operations to secure maximum benefits and economies of each, and flocculation improves settling characteristics of the floc. Describing mechanical agitating devices, the author described the advantages of horizontal blade types as flexibility, efficient utilization of chemicals, and the elimination of short-circuiting.

The various models of clarifiers now available possess advantages in sludge removal, lower operation cost, and

J. S. Long, Supt., Distrib., Tampa, Fla. Laments appointment of non-technical Water Supts.

Geo. F. Catlett, Recently Appointed Chief Engr. of Florida's Dept. of Health

Dr. W. A. McPhaul, State Health Officer. Malcolm Pirnie, Consultant to many Florida Water Works. S. Paige, Geologist, U. S. Engineer's Office, Ocala

the production of higher density sludge. He discussed the compartment settler in which the full depth is divided into a number of shallow basins, mechanically cleaned. In this, a large proportion of the total depth is used for settling, giving a greatly increased surface area. Since it is not always possible to predict with certainty how various factors will affect ultimate results, study and experimentation, before plant design, is very desirable.

E. L. FILBY, of Black & Veatch, Kansas City, in discussing Mr. Kahn's paper, said the compartment settler had not proved entirely successful when tried several years ago. While mechanical equipment has been of great importance in modern plant design, he believes careful control of chemical application and even redesign of equipment may make for better efficiency and lowered cost.

CHRIS BINGHAM, Supt., Filtration, Richmond, Va., said that the James River, above Richmond, received sulphite wastes and the raw water preparation was all-important. Flocculators had proven more important in conditioning than control or adjustment of pH, and had, consequently, effected a very marked saving in chemicals required.

"The Physiological Effects of Mineral Salts Present in Natural Waters"—By DR. C. B. POLLARD, Prof. of Chemistry, University of Florida, was an unusual topic received with considerable interest. To account for ideas as to the curative properties of mineral waters, Dr. Pollard showed that results from uncontrolled, unscientific experiments had been accepted. Drinking distilled water would probably produce the same results as mineral waters if consumed under similar conditions of rest and changed environment. Since it has been shown that only small amounts of calcium salts can enter the circulation, hard waters have been exonerated from blame for such conditions as urinary concretions. Statistical evidence shows no relation between hardness of water and deaths.

Mentioning briefly the effect of chlorides, nitrates, and metallic salts in water, the speaker pointed out that few waters contain sufficient amounts to be of pronounced physiological effect. Considerable research is new being carried out in respect to the fluorine content of Florida waters.

Round Table Papers

"Rebuilding of Filters at West Palm Beach." J. R. TANNER, West Palm Beach. By means of motion pictures, Mr. Tanner showed methods used to correct clogging of 3-inch underdrains and to remove spots of impervious material collected between the sand and gravel layers. Discussion following, evoked the fact that mud balls are a widespread source of trouble. Mr. Burnett pointed to the success of prechlorination in making these break up easily by the weekly use of a fire hose. J. E. Lyles, Tampa, found too high a wash rate responsible for uneven level of gravel—particularly at ends of pipes. Lowering the wash rate had corrected the condition in six months. W. N. Jones said that the use of a screen to separate sand and gravel layers had proven unsatisfactory because of carbon dioxide content of the water. By proper manifold construction no mixing of the layers would take place.

Discussing **"Problems in Sterilization of Water with Chlorine and Ammonia,"** HARRY A. FABER, The Chlorine Institute, New York City, said proper approach to the problem depended upon the type of water to be treated, and the purpose of the treatment. In Florida, well supplies predominate and their chlorination is a desirable treatment as insurance against contamination from heavy pumping and unusual wet season contamination. Some of these supplies have given "red-water" trouble in dead ends and chloramine application is of value in correcting this condition as well as tuberculation by bacteria. In the case of filtered supplies, the economic value of prechlorination has been proven in many plants. When the water does not contain taste producing substances prohibiting this method of application, ammonia addition subsequent to chlorination offers a distinct advantage in that sterilization is more rapid, the residual is lasting, and chemical cost is decreased.

In answer to a question by J. P. TURNER, JR., Florida Public Service Co., as to the proper point of chlorine application when aerating a water containing hydrogen sulphide, Mr. Faber showed that economy would indicate its use following aeration. In this case, the chlorine demand would be decreased through sulphide removal by the aeration process. Further, chlorine would not be lost by volatilization.

"Chloramine Treatment for Control of Iron Bacteria." KEITH CHINN, Chemist, West Palm Beach, Water Co.

The study of tubercules disclosed some remarkably resistant organisms which apparently reproduced by budding and could not be destroyed by boiling. Laboratory experiments did not prove chloramine treatment would kill them, but semi-plant scale work showed that though organic matter prevented even a heavy dose from carrying a residual through the filters, growth of the organisms was stopped. Carrying a caustic alkalinity in the water corrected had partially stopped red-water troubles, but the chloramine treatment ended tubercule formation and red-water, and had other advantages to its credit. Filters are maintained in excellent condition, there has not been a single red-water complaint in months, and reasonable residuals are maintained in all parts of the distribution system—even in dead ends. This effect is being studied by periodic examination of a separate section of cast iron pipe, through which the treated water flows continuously.

Prof. T. M. Lowe (Hydraulics), Univ. of Fla. C. F. Underhill, Comm. Utilities, Orlando, Fla. D. S. Wallace, U. S. Geol. Survey, Ocala, Fla. (Elected Vice-Chairman of Section)

MALCOLM PIRNIE, advisor to the West Palm Beach Co., in discussing developments in correcting the condition said that in the beginning a high free alum content was passing the filters, producing a bad red color. The modified Hatfield haematoxylin test has proven far superior to the old logwood test, and is used for daily analyses. Residual alum is now kept under 0.03 p.p.m. by adding (when necessary) to the raw water another water with a high bi-carbonate alkalinity, taken in sufficient quantity from drilled wells, to react with all the alum.

A. P. BLACK, reporting studies made on the red and black sediment found in mains, showed the presence of iron-fixing bacteria, exceedingly difficult to cultivate. The explanation of the condition seemed to be that when water stood in dead ends for a long time a black precipitate was formed from bacterial reduction of sulfates to sulfides and consequent iron sulfide production by reaction of the hydrogen sulfide on the iron. In waters which have stood a shorter period of time only the reddish iron color is present. Sulfide production does not take place where water is in rapid motion or is maintained in practically a sterile condition.

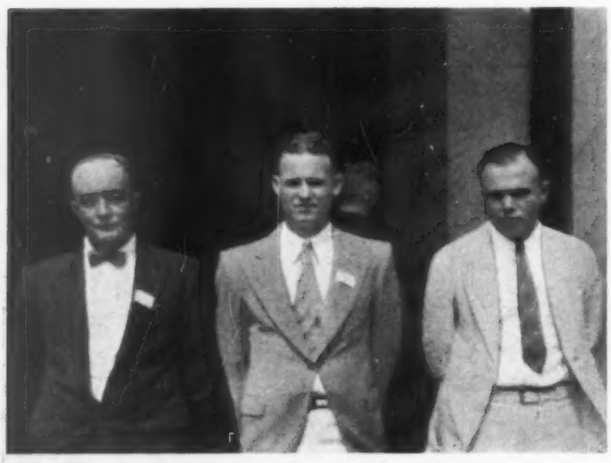
"Control of Tastes and Odors." F. E. STUART, Development Engineer, The Activated Alum Corp., New York City.

Reviewing changes in methods of carbon application in coagulation, taste, and odor control, Mr. Stuart described the addition of carbon directly to the filter after washing as desirable. If this is followed by a small additional dose, added continuously with the applied water, coagulation is aided and sludge decomposition in settling basins is prevented. He recommends that about 4 pounds of carbon per m.g. filter area be applied *after* washing, and that "Activated Alum," if used as the coagulant, will supply the additional carbon.

The use of copper sulphate in combination chloramine addition seems to promise better algae control. Carrying extremely high chlorine residuals to the filters had been observed by Mr. Stuart to hinder taste and odor control, whereas lowered doses seemed as effective in lengthening filter runs.

External Pipe Corrosion

J. T. MACKENZIE, Metallurgist, American Cast Iron Pipe Company, Birmingham, presented a thorough review of **"Underground Corrosion."** The Bureau of Standards, he said, had done the most complete work reporting (Technical Paper No. 368), a survey of conditions from a study of 36 representative soils. Pipe specimens laid at the usual levels were excavated after definite periods and the degree of corrosion of different materials under different climatic conditions reported. The conclusion reached is that soil corrosion is essentially electrochemical, because of currents set up by potential difference of the materials in the surface of the pipe itself. In acid soils, though cast iron pipe may have a protective tar coating, if a small metallic area is exposed rapid corrosion may take place. Most action occurs in the areas of deficient oxygen supply, especially in salt water marshes. The principal types of "rusting-sands" were to be found in Florida and, to prevent galvanic currents, it was advantageous to use lime in backfilling unless considerable organic matter was present. Laboratory test methods employing the soil available and plates of the metal to be used in the pipes were described. The plates were immersed, connected to a source of current, and the rusting action hastened—a good correlation being obtained with conditions in actual practice.



Tampa Plant Operators

H. A. Porter; W. E. Hicks; W. Wilder, Chemist, who work for J. E. Lyles, Supt., Purification. (We regret that our Scotch photographer took Jo. Lyle's and Secy. Hoy's pictures on the same film—so both are missing from this report.—Ed.)

"Recent Advances in Sewage Treatment" was the title of a comprehensive paper by G. F. CATLETT, Chief Engineer, State Board of Health, Jacksonville.

Mr. Catlett complimented the Federation of Sewage Works Associations as an important factor in the research which has given us a more scientific understanding of the nature of processes available for treatment. Contributions of the Sewage Works Journal and of such organizations as The Chlorine Institute, Guggenheim Bros., and some equipment manufacturers have become important in stimulating more efficient plant operation.

Recently there has been less tendency to use fine screening and, instead, to use one process for the removal of all solids. Indications are that sedimentation tanks, except for use in chemical coagulation, will gradually become as obsolete as the old septic tanks. Trickling filters will continue to maintain their place where sedimentation is the primary treatment, and where the degree of treatment produced is adequate. Citing the erratic results common to activated sludge plants, the expense of supervision and operation, and patent decisions, Mr. Catlett said these have all had an effect on the earlier enthusiasm for the process. In sludge digestion the value of research has perhaps been best demonstrated. Renewed interest in power production from digestor gas, recent work in connection with garbage disposal by sewage treatment procedures, and success in sludge incineration constituted important present trends.

The uses of chlorine continue to grow. In addition to final sterilization, odor prevention, prechlorination to prevent septicization, biochemical oxygen demand reduction, and control of aquatic plants in streams below sewage outfalls are obvious advantages. In sludge thickening, in controlling bulking of activated sludge, and in trade waste treatment it had proven likewise successful. Newer equipment and better understanding of sewage had been responsible for promising developments in the chemical methods of treatment. The mechanical filter serves as a desirable secondary treatment for complete clarification. Chemical treatment has proven particularly adapted to wastes of the seasonal industries such as canning, and is applied in the field of industrial wastes with marked success.

DR. A. P. BLACK complimented Mr. Catlett for presenting a survey of sewage developments in terms inter-

esting and understandable to the average water works man.

E. L. FILBY mentioned that the delicacy of the biological processes was largely responsible for adoption by bolder municipalities of chemical treatment methods in which heavier loads were possible. A capable manager of both water and sewage was warranted, in his opinion, by the importance of careful supervision of both and sewage treatment should be paid for by sewer rental.

Adding that the flexibility of chemical treatment gave it very desirable advantages, HARRY A. FABER mentioned instances in which this process handled wastes impossible of adequate treatment by biological means. Not only was chlorine alone important, but such combinations as chlorinated iron for hydrogen sulphide removal and chlorinated-copperas for coagulation, have prove to be valuable adjuncts. Because of the similarity in their fields, water works men, he pointed out, should follow closely the developments in sewage treatment.

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Exhibitors at A. W. W. A. Convention

(List as of May 1, 1936)

The American Brass Company
American Cast Iron Pipe Co.
American City
American Concrete & Steel Pipe Co.
Art Concrete Works
The Atlas Mineral Products Co. of Pa.
Badger Meter Mfg. Co.
Builders Iron Foundry
California Corrugated Culvert Co.
The Central Foundry Company
Chicago Bridge & Iron Works
Crane Company
Darco Corporation
DeLaval Steam Turbine Company
The Dorr Company, Inc.
Ducommun Metals & Supply Co.
Engineering News-Record
Fairbanks, Morse & Co.
Ford Meter Box Company
Forni Manufacturing Company
Hershey Manufacturing Co.
Hydraulic Development Corp.
Industrial Chemical Sales Co.
International Filter Co.
Iowa Valve Company
Johns-Manville
James Jones Company
Kennedy Valve Mfg. Co.
The Leadite Company
Mueller Company
National Meter Company
National Water Main Cleaning Company
Neptune Meter Company
Pacific States Cast Iron Pipe Co.
Pardee Engineering Company
The Permutit Company
Phoenix Meter Corporation
The Pitometer Company
Pittsburgh-Des Moines Steel Co.
Pittsburgh Equitable Meter Co.
Reliable Iron Fdry., Inc.
Rensselaer Valve Co.
Simplex Valve & Meter Co
The A. P. Smith Mfg. Co.
S. Morgan Smith Co.
Sparling Water Measuring Equipment
Thomson Meter Corp.
United States Pipe & Fdy. Co.
United States Steel
Wailes-Dove-Hermiston Corp.
Wallace & Tiernan Co., Inc.
Water Works & Sewerage
Water Works Engineering
Western City
Western Construction News
The Western Gas Construction
Western Pipe & Steel Co. (of Calif.)
R. D. Wood Company
Worthington-Gamon Meter Company

P. S. Wilson Appointed Acting Secretary A. W. W. A.

B. C. Little becomes Secretary-Emeritus; A. V. Ruggles resigns.

P. S. Wilson

On May 1st, P. S. Wilson, of Glen Ridge, N. J., who is Secretary of the recently formed New Jersey Section of the American Water Works Association, was appointed by President Frank A. Barbour as Assistant to the Secretary of A. W. W. A., filling the vacancy which resulted from the resignation of A. V. Ruggles.

Mr. Ruggles henceforth will devote his entire efforts to the work of the Sectional Committee on Cast Iron Pipe and Fittings, which he has been serving, as Technical Assistant to Chairman Thomas H. Wiggin, for the past several years. Mr. Ruggles may still be reached through A. W. W. A. headquarters or at his new address.

Upon the retirement of Beekman C. Little on May 1st from active duty as Secretary, to that of Secretary-Emeritus, which position carries an annual honorarium of $2,500 per year from the Association, President F. A. Barbour named Mr. Wilson Acting Secretary until such time as a new Secretary can be selected. Assumedly some definite action will be taken by the A. W. W. A. Directors during the Los Angeles Convention, on the matter of Mr. Little's retirement and the naming of his successor.

Mr. Little felt that he should not move from his home in Rochester to live in New York City or its environs, in order to give more direct attention to the headquarters office work. The need for closer supervision and management of the offices, explains the recent changes made on May 1st by the General Policy Committee, and the additional changes in the making. It is generally understood that Mr. Little would not have been retired, other than for the reason that it was his wish not to remove from Rochester to the Association headquarters city.

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Martin Flentje Joins American Water Works and Electric Company

Martin E. Flentje, of Greenville, Pa., for many years Superintendent of Purification with Community Water Service Company, has been retained by American Water Works and Electric Company — the outgrowth of the recent purchase of Community's chain of plants by American. His headquarters will be in New York City.

M. E. Flentje

Mr. Flentje will be working out of the company's Sanitary Engineering Department, headed by C. E. Trowbridge, who for many years has served as Chief Sanitary Engineer and Chemist of the company.

AUTOMATIC SOFTENING AND IRON REMOVAL PLANT AT EAST LANSING, MICH.

By FRANK R. THEROUX*

East Lansing, Mich.

EAST LANSING formerly used a well water supply which was objectionable principally because of its hardness and iron content. In order to overcome this condition, many of the homes installed zeolite water softeners and others used rain water collected in cisterns and distributed by household pumps. All homes so equipped have duel plumbing systems, the soft water being used only for purposes requiring the use of soap and sometimes for cooking. Homes equipped with softeners generally found it necessary to regenerate them weekly. Houses with cisterns and pumps often neglected their upkeep with resultant leaky cistern walls, dirty water, or pump failures and in drought years the cisterns were frequently dry.

A vote taken in the spring of 1933 was overwhelmingly in favor of constructing a water softening and iron removal plant with the assistance of the PWA. It is believed that as many people with household softeners or cisterns voted in favor of the project as people without soft water. The value of a continuous supply of soft water is realized even more by those used to soft water than by those using hard water continuously.

Character of the Water

The water is taken from wells about 400 feet deep and is typical of ground water in this part of the State. Of principal concern is the hardness of about 18 grains, the iron content of about 1 part per million and free carbon dioxide of about 30 parts per million. A typical analysis shows the following values:

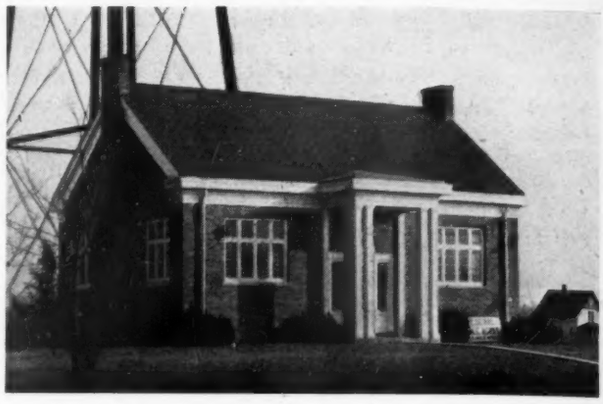
	Parts per million
Total Solids	327
Calcium	75
Magnesium	27
Chlorides	2
Sulphates (SO_4)	18
Silica (SiO_2)	1.2
Iron	1
Free CO_2	30
Alkalinity (m.o.)	284
Hydrogen Ion (pH)	7.2
Temperature	50°F

While the hardness was the principal continuous objectionable quality of the water, iron was a close second at times. The iron content and growths in pipes brought frequent complaints of objectionable iron stain and tastes.

The Treatment Process

The objects of the treatment process are: (1) to reduce the hardness, (2) To remove the iron, and (3) To remove the free carbon dioxide and raise the pH value.

These objects are accomplished in an automatically operated plant. The same well and pump are used as before the plant was built. The water formerly was pumped directly from the well, by a centrifugal deep well multi-stage pump, to the distribution system and elevated storage tanks. The treatment plant was inserted as a pressure plant between the well head and the distribution system, thus making use of existing pumping equipment.



East Lansing Automatic Zeolite Softening and Iron Removal Plant. Capacity 1 M.G.D.

All normal operations are controlled by electrically and hydraulically operated mechanisms which carry on the ordinary procedures in the plant without the presence of an operator. It is, of course, necessary to regularly inspect the plant and at times make certain adjustments. There is no operator on duty at any certain time, although the plant is on duty 24 hours daily. (Visitors will find the plant locked, but inspections are welcomed, although it will be necessary to call at the city hall or at the office of the author first.) It is believed that this is the most completely automatically operated municipal water treatment plant in the United States. The plant has a capacity of 1,000,000 gallons per 24 hours.

Three-fourths of the water is softened by passing it through five cylindrical zeolite softening units. Each unit is seven feet in diameter and eleven feet high and contains a bed of 200 cu. ft. of green-sand zeolite, making a bed depth of 5.19 feet. The zeolite sand is supported on a bed of gravel 12 inches in depth, underlaid with a strainer system. The zeolite sand has an exchange capacity of 2800 grains of hardness per cu. ft. or 560,000 grains per tank. With water of 18 grains hardness, as in East Lansing, it is thus possible to soften about 31,000 gallons per tank beween regenerations. This softening capacity is used up in 260 minutes at the present rate of pumping. Regeneration is accomplished by passing a brine (sodium chloride) solution through the softener. The iron content of the water is also removed by these softening tanks in the same manner as the calcium and magnesium.

The other one-fourth of the water is passed (untreated) through two tanks of the same size as the softening tanks, each containing 100 cu. ft. of a special manganese zeolite, capable of removing iron by oxidation and filtration, but having no effect on the hardness producing compounds of calcium or magnesium. It will be noticed that this a process of oxidation and filtration and not a base exchange as in the softening tanks.

*Assoc. Professor of Sanitary Engineering, Michigan State College.

The two flows, mentioned in the two preceding paragraphs, and then mixed, giving a water from which three-fourths of the hardness and all of the iron has been removed.

This mixed flow is treated with a solution of caustic soda and sodium silicate for the purposes of removing the free carbon dioxide in the water and to deposit a protective silica coating on the inside surfaces of the water pipe. A carefully proportioned amount of this caustic solution is injected into the water, as it leaves the treatment plant, by means of the pressure drops created by use of primary and secondary orifices.

Amounts of Chemicals Used and Their Cost

Sodium chloride (common table salt) used for regeneration of the softeners is the principal item of expense in the operation of the plant. Salt costs $7.85 per ton delivered at the water softening plant. With the present water consumption of 350,000 gallons per day this requires 1720 lbs., or a daily expenditure of $6.75. This is a unit cost of 1.93 cents per 1,000 gallons. (Recent quotations on salt indicate the unit cost may be reduced to 1.63 cents per 1,000 gallons.)

Potassium permanganate used for regeneration of the iron removal tanks costs 26 cents per pound. About 40 pounds of it is used monthly. As one-fourth of the plant flow passes through these tanks the cost amounts to 0.4 cents for each 1,000 gallons treated for iron removal, which adds 0.1 cent per 1,000 gallons to the entire plant flow cost.

To maintain a satisfactory application of caustic solution, used to remove free CO_2 and raise the pH, requires 175 pounds of caustic soda per 1,000,000 gallons. Caustic soda costs 4 cents per pound. This represents a cost of 0.70 cents per 1,000 gallons.

The entire cost of chemicals for the three treatments mentioned above is 2.73 cents per 1,000 gallons of water delivered to the distribution system.

The additional electrical energy used to force water through the treatment plant may be measured by the drop in pressure through the plant of 13 pounds. The pressure entering the plant is 65 pounds and on leaving the plant is 52 pounds. At the present cost of electrical energy of 2½ cents per K.W.H. this increases the pumping cost 0.4 cents per 1,000 gallons.

Cost of Plant

The treatment plant, completely equipped, cost about $21,000.00. The PWA paid 35 per cent and the city 65 per cent, thus making the investment cost the city about $14,000.00.

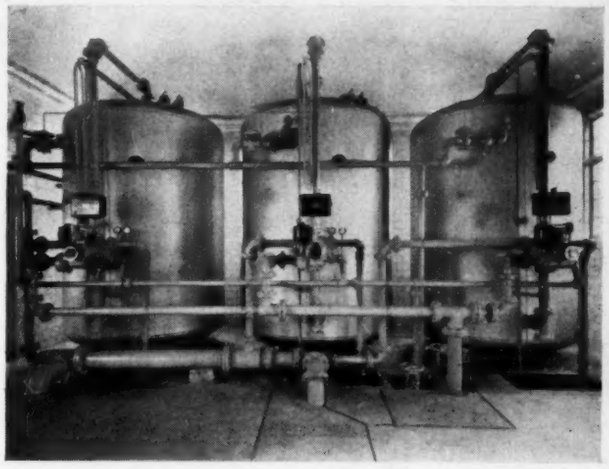
COST OF TREATMENT

(Based on present delivered flow of 350,000 g.p.d.)

	Per 1,000 gals.
Fixed charges (7½% of $21,000.00)*	$0.0123
Chemicals	0.0273
Power	0.0060
Plant Supervision and attendance	0.0119
Miscellaneous	0.0010
Total	$0.0565

The plant has a capacity of 1,000,000 gallons per 24 hours. The above costs are based on the present flow of 350,000 gallons per 24 hours. The estimated cost with plant capacity fully utilized is, of course, somewhat lower. Some of the above figures are only approximate, as the plant has not been in operation long enough to determine values more closely.

*Note: It strikes us that the "Fixed Charges" should be computed on only that sum invested by the city ($14,000) and not on the value of the gift of PWA in addition.—Editor.



Three of the Five Zeolite Units, East Lansing Plant.

Explanation of Automatic Features

Pumping of water through the plant is at a constant rate, thus making it possible to control the softening cycle of a softener unit on a timed basis. An electrical sequence-time-switch is provided for this purpose, initiating the automatic regenerations of the softeners at timed intervals and in a definite sequence. This switch is a synchronous motor driven device with five normally open load circuits (one for each softening tank) and one resetting circuit. The resetting or overall cycle is set at the useful softening period plus the regeneration period of a unit. The load circuits are then set in sequence so that all five softeners will regenerate within the overall cycle but so that only one unit is regenerated at a time.

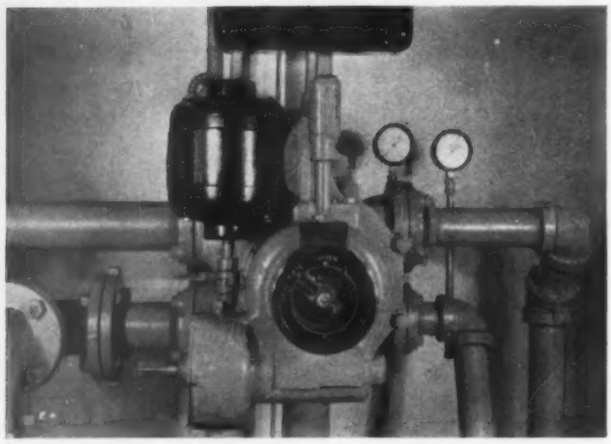
Each softener is equipped with a motor operated multiport valve. The operation of this multiport valve controls the regeneration of the unit. After the sequence switch has started the regeneration of a unit, the steps in the regeneration process are controlled by a timing motor and float controlled switches. The steps may be described as follows:

1. Unit produces soft water (by downward flow through the zeolite at rate of 3 gallons per sq. ft. per min.) for the predetermined time interval, after which the electrical sequence timing switch makes a contact initiating the regeneration.

2. The multiport valve (motor operated) moves from the softening to the wash position. This cuts the unit out of service and backwashes it with raw water at a rate of six gallons per sq. ft. per min. This water leaves the unit at top and passes to the sewer. The wash period is ten minutes and is controlled by a time switch.

3. The multiport valve moves to the brine position. An electrical contact starts a motor driven pump on a brine recovery tank, pumping recovered brine through softener. When recovered brine has been used up, a float switch cuts off the brine pump motor and a solenoid controlled diaphragm valve opens, permitting an ejector to introduce a measured quantity of fresh salt brine into the softener. As this passes through the softener the first portion, that is the previously recovered brine, is run to waste. When the proper volume of fresh brine has been ejected, a float switch in the brine tank operates to close the solenoid controlled diaphragm valve, thus stopping the ejector.

4. The multiport valve moves to the rinse position. Raw water enters the top of the softener and rinses



The Motor-Driven Permutit Multiport Valve—the Heart of the Automatic Control.

the brine through the softener, a second solenoid controlled diaphragm valve, opening so that this fresher brine and rinse water flows to the brine recovery tank to be used for the first portion of the regeneration of another unit. This brine recovery system effects marked economies in the use of the salt. The rinsing continues until all of the calcium and magnesium chlorides, produced in the regeneration, plus excess salt, have been rinsed out of the unit, the last portion, which is too dilute for re-use, being automatically discharged to the sewer.

5. The multiport valve moves to the softening position, thus restoring the unit to service.

Chemistry of the Treatment Processes

Softening

The calcium and magnesium bicarbonates and sulphates cause the hardness in the East Lansing water. The zeolite used is a highly processed greensand base zeolite which has the property of exchanging its sodium for the calcium and magnesium of the hardness producing compounds in the water. The sodium zeolite compound may be indicated by Na_2Z and the softening reactions are:

$$Na_2Z + Ca(HCO_3)_2 = CaZ + 2NaHCO_3$$
$$Na_2Z + CaSO_4 = CaZ + Na_2SO_4$$
$$Na_2Z + Mg(HCO_3)_2 = MgZ + 2NaHCO_3$$
$$Na_2Z + MgSO_4 = MgZ + Na_2SO_4$$

The sodium zeolite, during the softening run, changes to a calcium or magnesium zeolite, while the hardness producing compounds of calcium and magnesium in the water are replaced by the corresponding sodium compounds. For a water containing the relative amounts of calcium and magnesium compounds as in East Lansing, it is interesting to note the weight of dissolved solids in the treated water is about the same as in the raw water.

The regeneration of the zeolite is accomplished by passing a sodium chloride (common salt) brine through the zeolite bed. The reactions are:

$$CaZ + 2\,NaCl = Na_2Z + CaCl_2$$
$$MgZ + 2\,NaCl = Na_2Z + MgCl_2$$

The calcium and magnesium zeolites are changed back to sodium zeolites and are ready for softening again. The resultant calcium and magnesium chlorides plus excess salt is then thoroughly rinsed out of the zeolite bed before it is again placed in service to soften water.

Iron Removal

Iron compounds are removed in the softening units by an exchange process similar to that described above for removal of calcium and magnesium compounds.

The two units which remove iron only, but exert no softening action, contain a manganese zeolite, instead of a sodium zeolite as in the softening tanks. Higher oxides of manganese ($MnO\ Mn_2O_7$) are carried on the surface of the zeolite grains. These oxides give up oxygen to the iron compounds in the water, thus throwing the iron out of solution. It is then filtered out of the water by the bed of manganese zeolite sand. The zeolite acts simply as a carrier of the manganese oxides and as a catalytic agent. The reaction may be expressed as folows:

$$Na_2Z + MnO{:}Mn_2O_7 + 4\ Fe(HCO_3)_2 = Na_2Z + 3MnO_2 + 2\ Fe_2O_3 + 8\ CO_2 + 4H_2O.$$

The higher oxide of manganese is restored by passing a potassium permanganate solution through the bed.

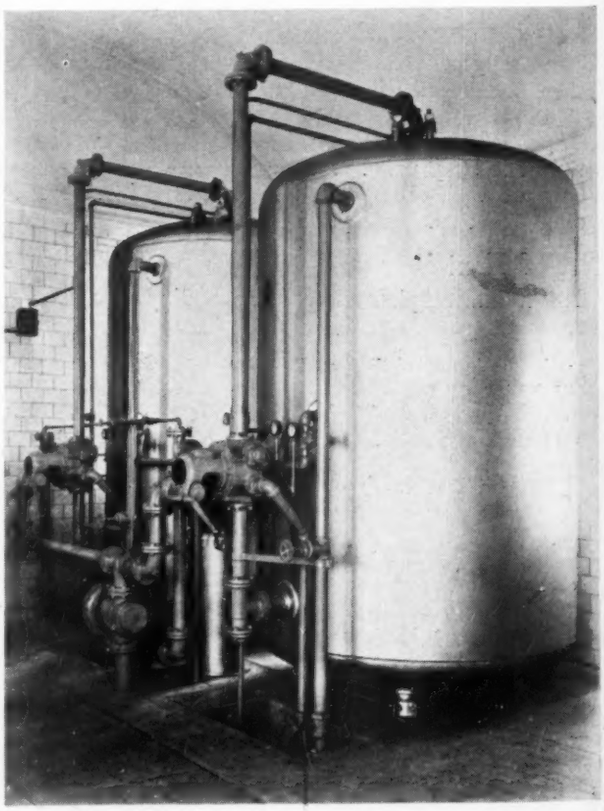
Free Carbon Dioxide

Free CO_2 is reduced by adding a solution of caustic soda. This results in raising the pH from 7.2 to 8.0. The reaction is:

$$Co_2 + NaOH = NaHCO_3$$

Except during the first few months, when adjustments of some of the many mechanical features were necessary, very little attention has been required from those responsible for the plant operation.

The general design was by Claude E. Erickson, Consulting Engineer of Lansing, Michigan. The details of design of all equipment and the zeolite were furnished by the Permutit Company of New York City. Acknowledgment is due this company for the use of the illustrations accompanying this article.



The Manganese Zeolite Units for Removing Iron or Manganese from the Non-Softened Water.

THAT A. W. W. A. MAY GO FORWARD

A Statement* Just Released by the Chairman of the General Policy Committee of A. W. W. A.

EARLY in 1935, the Board of Directors of the "General Policy Committee" to study the past progress and means of future development of the organization. The committee consisted of Messrs. GG. H. Fenkell, R. L. Dobbin, G. W. Pracy, M. Pirnie, H. E. Jordan and F. A. Barbour (past presidents and president of the Association) and Mr. D. F. O'Brien (past president of the Water Works Manufacturers' Association). A preliminary report was made by the committee at the Cincinnati conveniton and a formal report was made at the annual meeting of the board in New York City in January of 1936.

Portions of that report were:

"Your committee recommends to you the four following expressions of policy:

"(1) As a means of stabilizing the influence of this Association in water works affairs, it should maintain a well planned membership expansion program.

"(2) The Association should encourage the organization of more sections within single state boundaries in order to capitalize the already existing unity of interest.

"(3) It should establish definite and effective contact with other organizations interested in the improvement of municipal administrative practice.

"(4) The Association should set up as a major and continuous program the improvement of status of all water works personnel.

"To make these, as well as other correlative aims effective, your committee has given much study to the present administrative staff and its performance. It is aware of the virtue of the previous administrative reorganizations, for the purposes and at the times at which they occurred. It is fully appreciative of the quality of service rendered by the staff within the field which they have considered to be their proper scene of activity.

"Your committee is fully convinced that for the future good and progress of the Association, a redefinition of administrative functions is imperative and that incidental thereto certain changes in personnel may be required. Emphasis needs to be made and activities undertaken both of which demand more active direction than our staff now receives.

"The first and major redefinition of duties relates to those of the secretary. In addition to the constitutional and somewhat traditional duties of this office, an extension is needed to the end that the secretary become the continuous active administrative head of the Association. Not only is it necessary that he be a resident of the headquarters city or its immediate environs, but also that he be in a position to give full time to the planning and execution of Association activities. He must be a person of demonstrated executive ability, capable of stimulating activity in the interest of the Association among all classes of members. He must be recognized as a leader by all classes of Association membership and capable of promoting the interests of the Association among manufacturing and municipal executives. To him should be added the duty of continuous and active direction of Water Works Practice committees, subject to the advice and counsel of the Chairman of the Committee. He should be permitted to contact the members of the Association in section and national meetings fully enough to enlist the services of the newly active members in worth while Association work.

"Under him, as soon as reorganization could be made effective, should serve a Technical Assistant and a Membership and Finance Assistant. To one, in proper time, should be assigned the routine technical work in connection with water works practice and also the editorship of all the Association's publications. To the other should be assigned the membership activities and the promotion of advertising income.

"A General Secretary and two typists complete the resident office staff. The Technical Assistant would require certain additional part time service in relation to the Journal.

"The salary budget for this staff should total not much over $26,000 per year, with the Secretary receiving $10,000-$12,000 per annum for his work.

"It is the judgment of your committee that, if the Association is to keep step with the needs and opportunities of the field, such reorganization needs to be made effective as soon as it can be courteously and effectively arranged. Obviously the Association must recognize the past services of its present Secretary by an emeritus designation and a reasonable annual honorarium.

"When such changes are made, it will be possible for the Association to move definitely forward along lines of adding members, organizing additional sections and contacting other municipal organizations, all to the ultimate end of increasing the influence of this Association and giving greater stability and economic security to the men in the water works field."

The Board of Directors charged the General Policy Committee with the task of putting the recommended changes into effect. Much study was given to the detailed problems involved. It was fully recognized that Mr. B. C. Little had given the Association much good service as Secretary. That he was unwilling to take up his duties in the headquarters city made his continuance in the office impossible. The committee also felt that the Association needed a somewhat different type of administrator to meet its growng needs and agreed that Mr. Little should be made Emeritus Secretary as of May 1, 1936, with full Secretarial salary up to July 1 and an emeritus honorarium thereafter of $2,500 per year.

Mr. P. S. Wilson was made Acting Secretary on May 1st and Mr. A. V. Ruggles, who has been Technical Assistant to the Secretary retired from duty.

The appointment of a Secretary has not been made. The Editor of the Journal, Mr. Abel Wolman, will continue his duties until the administrative changes are complete. Thereafter the Journal will be edited by the headquarters staff.

Signed: HARRY E. JORDAN.

*This statement has been received just as this issue goes to press, and after the preparation of the comments made on the Editor's page.—Ed.

A QUICK METHOD OF MAKING WET TAPS

By E. T. CRANCH

Manager New Rochelle Water Co.

E. T. Cranch

IT is assumed that all water works men are familiar with the ordinary hand operated machines for the making of wet-taps for branch connections. These machines have been on the market for many years and have certainly saved water works men many hours of labor. It has also eliminated the inconvenience to the consumer of having to get along without water for several hours while a tee is being cut in the line and a valve installed on the branch line, as was the case in the past.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

Hand Operated Tapping Machine Equipped with Labor and Time Saving Air-Motor Drive.

For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

The accompanying illustration shows this machine in operation.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

▲

Association Meetings Scheduled:

MAY 27—WANAQUE, N. J. (Reservoir).
New Jersey Section, A. W. W. A. Secy., P. S. Wilson, Glen Ridge, N. J.

JUNE 8-12—LOS ANGELES, CALIF. (Hotel Biltmore).
American Water Works Association (Annual Convention). Acting Secy., P. S. Wilson, 29 West 39th Street, New York, N. Y.
(California Section, A. W. W. A., will hold its Annual Business Session during the Convention on June 10th.)

JUNE 11-13—LIDO BEACH CLUB, N. Y. (Near Long Beach, L. I.).
New York State Sewage Works Association (Spring Meeting). Secy.-Treas., A. S. Bedell, State Department Health, Albany, N. Y.

JUNE 22-26—STATE COLLEGE, PA. (Penna. State College).
Pennsylvania Water Operators Association (June 22-24). Secy.-Treas., I. M. Glace, 20 So. 22nd Street, Harrisburg, Pa.
Pennsylvania Sewage Works Association (June 24-26). Secy., L. D. Matter, State Department Health, Wilkes-Barre, Pa.

JULY 20-24—STILLWATER, OKLA. (Okla. State College).
Oklahoma Water and Sewage Conference (Annual Conference). Secy.-Treas., H. J. Darcy, State Sanitary Engineer, Oklahoma City, Okla. (Conference held in conjunction with Water Works Short School.)

AUG. 19-21—CLEVELAND, OHIO (Hotel Cleveland).
Central States Section, A. W. W. A. Secy.-Treas., H. Floyd Nelson, U. S. Pipe and Foundry Co., 2437 Koppers Bldg., Pittsburgh, Pa.

SEPT. 22-25—NEW YORK, N. Y. (Hotel Pennsylvania).
New England Water Works Association (Annual Convention). Secy., Frank J. Gifford, Room 613, Statler Building, Boston, Mass.

OCT. 12-15—FORT SMITH, ARK. (Hotel Goldman).
Southwest Section, A. W. W. A. (Annual Convention). Secy., Lewis A. Quigley, Supt., Water Works, Fort Worth, Tex.

EDITORIAL

Let's Know the Facts

AT the recent meeting of the Four States Section of A. W. W. A. a resolution was passed which has been widely circulated and publicized. It denounces the General Policy Committee of the Association for a single action taken in an authorized program looking toward the strengthening of the activities of the association and a reorganization of the duties and personnel of the headquarters staff. To be specific, its preamble objected to the "radical and drastic" action in retiring Secretary Beekman C. Little to the position of Secretary Emeritus. The resolution states:

"That, this Four States Section at its annual meeting at Baltimore, Md., April 23-24, 1936, hereby goes on record as being opposed to this or any action which will deprive this Section of the valuable services and untiring efforts of the present Secretary."

The above came about, to all appearances at least, as a consequence of Mr. Little's appearance before the Section on the previous day when he made public the actions taken by the General Policy Committee, including the notification from the president of A. W. W. A., terminating his duties as Executive Secretary on May 1st, and also the replacement of Mr. A. V. Ruggles, Technical Assistant to the Secretary. Mr. Little termed the notification to him as having been "most unexpected," in view of the fact that the Board of Directors in authorizing the General Policy Committee to make needed changes, had specifically stipulated that the Secretary should be continued in some capacity, and with compensation. In the actions taken, and those to be taken, Mr. Little commented that these contradicted the avowed policy of the Association in advocating tenure of office where faithful service had been rendered. He questioned the financial soundness of the proposal to increase headquarters' office expenses, and its effect on the Water Works Manufacturers' Association which would be expected to increase its contributions in all probability.

Closely on the heels of the circulated Baltimore resolution, came from the Executive Committee of another Section a similar disapproval addressed to President Barbour, and to other officials of the Association and its Sections. Then, came one from the New Jersey Section approving of the action taken by the General Policy Committee, but suggesting that in the future matters of such nature be given more publicity in order that the general membership of the Association become more effectively informed of such contemplated changes. Further, that matters of such import be presented to members of the Board of Directors at one meeting for decisive action at the succeeding meeting. (It is well to explain, in this connection, that 27 of the 28 directors were present when the Policy Committee, composed of outstanding members, was given unanimous authorization to proceed with the reorganization as there outlined. The report, with recommendations, was read three times to the directors, and discussed each time at some length between readings. Only then, was the resolution passed. During all of this process full minutes were being stenotyped and no discussion or action by the Board transpired in the absence of Secretary Little, or without hearing him. On this score the "most unexpected" action, as expressed by Mr. Little in his Baltimore speech, is difficult to understand; or, else, erroneous statements of his remarks have been recorded by reporters.) Following the Jersey Section resolution, the "shooting" died down and later resolutions have upheld the General Policy Committee in its action, an outcome based on reviews of the committee recommendations and records of action taken by the Board and subsequently by the committee.

It is difficult to criticize the well meaning members and officers of the Four States Section or the Trustees of the un-named Section for having given vent to their feelings in behalf of the gracious and lovable Secretary Emeritus of the Association. Criticism seems deserved, however, when it is realized that action was taken without the voting members having before them an accurate and full record of the history of, and actions in, the case. The un-named dissenting Section remains so because the Director representing the Section (likewise its Secretary) was the single absentee during the meeting of the Board at which authorization to act was given the Policy Committee.

Publicization of the action of the General Policy Committee by mails, magazines and through other channels has resulted in considerable current criticism and accusation against the committee, for its actions and motives, which have no justification. It is with some feeling, therefore, that WATER WORKS AND SEWERAGE is devoting this page to a review of the matter and, it is hoped may serve in correcting possible false impressions circulated intentionally or otherwise. One can hardly conceive of the General Policy Committee (consisting of five immediate past-presidents, the president and president-elect of A. W. W. A., and Dennis O'Brien, that venerable past-president of the W. W. Mfgrs. Assn.) as having other than the highest interests of the Association at heart in its recommendations and actions taken. This group surely must more perfectly than any other know the needs of the Association and the defects in the administrative organization. They have viewed the problems broadly and have taken actions which personally each member regrets the necessity of. They have been, with it all, fairly generous with the Secretary Emeritus, in establishing an annual salary of $2,500 to be paid him without limitations. That it has not shelved Mr. Little, is evidenced by the letter of notification to him stating that the committee's hope is that he will continue to take an active part in the future work of the Association. In it all, he has not lost any of the affection or admiration of a single official or members of the Association. By such action, his value to the Association (past and present) is acknowledged.

In view of the need for closer supervision and expansion of the activities of the administrative organization by a *resident* director, and Mr. Little's wish not to move to the headquarters city, the necessity of the action taken is apparent. It behooves the loyal members, genuinely interested in "What's Ahead for A. W. W. A." and the betterment to the official and social status of its individual members, to give support to the General Policy Committee and to the Directors in their acts which have been taken while looking to the fundamental interests of the Association. There is much of possible improvement that's ahead for A. W. W. A., and if courteous reorganization is needed to attain it there can be no dodging the issue.

Waste Disposal Engineering

IN THE most complete story yet written on the possibilities of disposing of municipal garbage, by way of dumping it into trunk sewers, appears in this issue. Reference is made to the article which comes from two engineers of long experience in sewage treatment—C. K. Calvert, Supt. of Sewage and Garbage Disposal at Indianapolis, Ind., and S. L. Tolman, formerly Engr. in Charge of Chicago's largest sewage treatment plant, and now head of the Sanitary Division of an important equipment manufacturer. These authors report on the "Effect of Garbage on Sewage Treatment" while, during a period of months, the entire garbage of Indianapolis was being ground (shredded), dumped into the sewage and handled at the treatment works as just so much added sewage loading.

Interesting, is the fact that the garbage gave little or no troubles at the treatment plant provided it was effectively comminuted by maceration, during the dumping procedure, to essentially preclude its dropping out in the grit-chambers or floating in settling units. More interesting, are the findings at Indianapolis in respect to the failure of such increased loadings in the form of greases and acid producing carbohydrates (oxygen consumed value) to upset the activated sludge process or the parallel flocculating bio-aeration process. The last consists of air blowing without return of sludge, and has been found economically and technically more expedient when weighing the overall accomplishments by the Indianapolis plant—the result of a comparison of the two methods.

Remarkable, is the revelation that so little effect was noted on the important qualities of the plant effluent during the periods of heaviest garbage loadings on the plant. With it all, the air requirements seemed to be less, if anything, during the garbage grinding period, when the sewage (without garbage added) was essentially of like quantity and quality as that of the previous season, the same being also said for operating conditions. With an excellent opportunity to compare the cost of transport by water carriage to the plant and disposal of garbage by the sewage treatment method, with established costs of trucking and disposal by the partially self-supporting reduction method as employed at Indianapolis, the marked economy of the sewage treatment method is a revelation which commands the attention of sanitary engineers and municipal authorities.

Under the circumstances at Indianapolis, where sludge digestion takes place in open lagoons, opportunity to determine the effects on plant scale tank digestion and gas production were lost but small scale observations, here as elsewhere, indicated a more rapid digestion of the sewage solids containing garbage than of the sewage solids alone. More gas was produced and herein is an additional important economic consideration.

The only known large scale effect on gas production and utilization by disposing of garbage through sewers was that observed simultaneously at Durham, N. C., during the summer of 1935, when grinding and water-carriage of a portion of the city's garbage to the new activated sludge plant produced a sufficient surplus of digester gas to supply electric power (gas-engine produced) over and above that required to operate the treatment works. Here, in consequence, something novel in American sewage works operation was made possible. Electric power was, at certain hours of the day, put out of the sewage treatment power station over the municipal wires to the city owned (hydro) power plant. So effective were the results that Durham is proceeding with a program involving permanent use of this method of garbage disposal to the maximum economic and technical efficiency which the extension of the program indicates to be permissible.

The chief requirements of this method of disposal of garbage seems to be an effective household separation of rubbish from the garbage and thereafter municipal separation of non-grindables and comminution of the garbage entering the sewers. In addition, a watchful control of input of solids to the digesters and possibly some minor adjustment of reaction (pH), or else an intermittent "resting" of digesters, may be required. With stage digestion and other modern methods, the Indianapolis results point, possibly, to a moderately increased digester capacity requirement—many times more than offset, however, by the value of the increased gas production where it can be utilized as fuel or in power production. Then, too, incineration of sludges from economical short-stage digestion tanks become more inviting than ever before, because of the added B.t.u. values in the gas and sludge which are garbage contributed in the form of greases, high volatile and carbonaceous matters.

The possibilities of chemical precipitation processes as applied to the garbage-sewage disposal scheme have not been investigated but where intermediate treatment of the combination may be all that is requisite the method is worthy of attention. Modern incinerators, capable of efficient and economical destruction of chemically precipitated sewage sludges, should be even more so in connection with such sludges—which are enriched with the highly carbonaceous garbage solids. The chief obstacle to economical garbage and sludge incineration have been the high non-drainable water content but with modern mechanical dewatering processes applicable to sewage sludges and precipitated comminuted garbage, or industrial waste sludges, the water evaporation bugaboo of incineration practice is no longer the formidable or costly problem that it has heretofore been considered.

With the progress made in uncovering the secrets, and dispelling the fears of many sewerage authorities, concerning the effects of garbage on sewage and sewage treatment practices, it seems that sanitarians very probably have in their hands the key which will open an important door to the economic aspects of wastes disposal. If the sanitarian finds it practicable to place sewage treatment on a self-supporting basis (possibly a profitable basis) by taking into the sewerage system the now costly disposed of garbage and industrial refuse of the city, his value will become so well recognized by authorities as to command remuneration and esteem which has long been deserving but only with difficulty, if at all, attained.

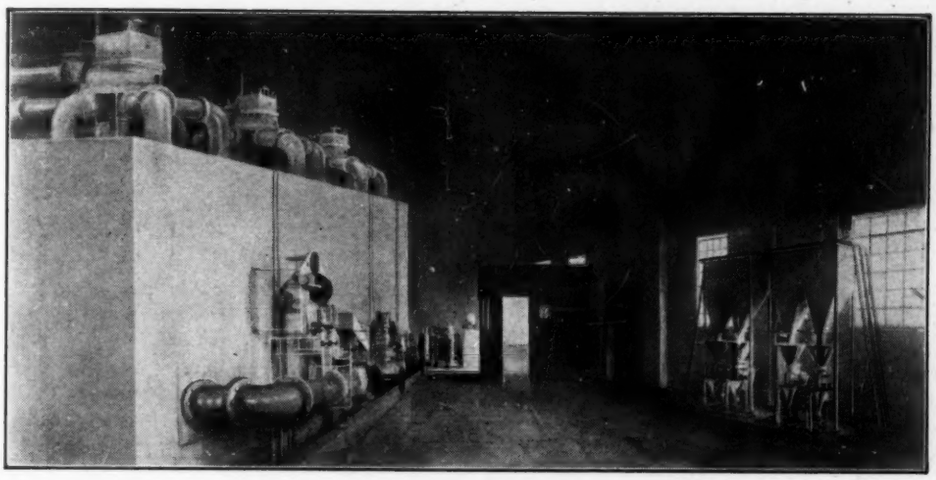
Water departments sometimes operate at a loss, but the water works produces something of value and thereby receives a degree of recognition. On the other hand, sewerage departments are notoriously non-productive in the sense of being profitable or even self-supporting. Little, if any, of the cost of sewerage operation is returned to the municipality and therefore the expense of operation is taken as an unavoidable drain and usually done to satisfy health authorities. Quite a different status would be accorded an efficient "Department of Wastes Disposal" which could satisfactorily dispose of sewage, garbage and rubbish in a single plant without duplication of operating personnel or managemnt, and overhead—with a possible material reduction of net costs, in line with those proven at Indianapolis and Durham.

L. H. ENSLOW.

Engineers...

Water Works Superintendents...

IF YOU ARE LOOKING FOR SOMETHING NEW THIS ILLUSTRATION HAS CAUGHT YOUR EYE



Enclosed Gravity Automatic Wash Multiple Unit Filtration Plant.

UNCONVENTIONAL IN DESIGN PERHAPS! BUT IT DOES FILTER WATER AND KEEPS ON KEEPING ON

Note the absence of external wash water piping. Extra high velocity wash and controlled sand expansion is obtained, without any external wash water circuit. Wash gutters are eliminated and the improved collector top with secondary sand expansion definitely eliminates mud balls and lowers wash water consumption.

THERE IS MORE IN IT THAN MEETS THE EYE. CABLE OR WRITE US FOR FURTHER INFORMATION.

FILTRATION & WATER SOFTENING PTY. LTD.

395 COLLINS STREET, MELBOURNE, C. L. VIC. AUSTRALIA

Cable Address: "FILTRATION, MELBOURNE, AUSTRALIA".

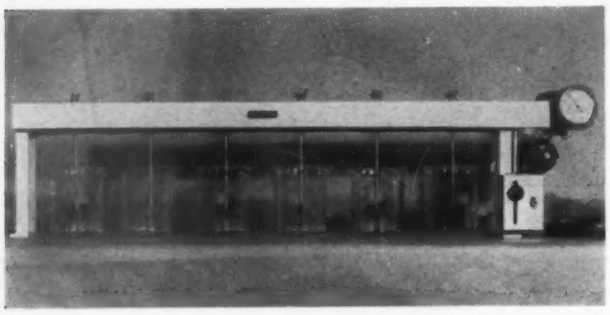
EQUIPMENT NEWS AND LITERATURE REVIEW

Phipps & Bird Laboratory Mixer

Phipps and Bird, Inc., of Richmond, Va., manufacturers of a complete line of laboratory equipment and chemical solution feeders, have announced a new and improved Laboratory Mixer and Flocculator for control of water coagulation and chemical precipitation of sewages and wastes.

Designed in co-operation with practical operators, features of the new flocculator include positive speed variations between 15 and 110 R.P.M of the stirring paddles, any one of which may be lifted clear of the sample for its removal or inspection. For this purpose lift-knobs are provided. Motor driven through rheostat control of the "Universal' type speed reduction unit, the positive chain-drive employed prevents speed fluctuations and minimizes friction. The useful tachometer (at right) reveals paddle speeds in R.P.M. direct.

The Phipps & Bird Mixer-Flocculator can be had in 3 to 6 unit sizes—each paddle being a unit. All sizes are built to the standard 9 in. width and 12 in. height. The 4 unit mixer is 34 inches long and



P. & B. Laboratory Mixer

the 6 unit is 46 inches. The base of neatly welded channel-iron gives rigidity and stability. The metal frame and covers are aluminum enameled. The paddles are of 20 B. & S. gage stainless steel (3x1 in.) and the shafts are of the same corrosion resistant metal.

The P. & B. Flocculator was designed "by an operator for operators." For further details address—Phipps and Bird, Inc., 915 E. Cary St., Richmond, Va.

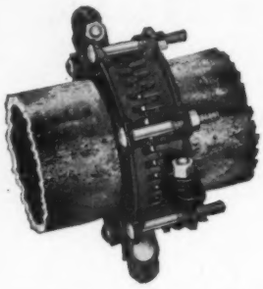
▼

Skinner Split Coupling Clamp

A useful three-purpose split coupling clamp has been brought out by M. B. Skinner Co., South Bend, Ind., for use in repairing "clean breaks" in cast iron pipe or stopping leaks.

This clamp, called the Skinner Split Coupling Clamp, repairs breaks permanently, and only requires a few moments' time on the part of one man to apply it. It not only stops the leak, but provides an element of flexibility at that point in the main which prevents future breaks in the near vicinity. It is made of malleable iron with cadmium plated steel bolts. The large heavy pressure gasket is sealed with a Monel metal sheath band which resists corrosion.

For illustrated literature, address M. B.



Skinner Split Coupling Clamp

Skinner Co., South Bend, Ind., who for 38 years have been producing pipe repair clamps and saddles.

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Simplex Pipe Pusher-Puller

Templeton, Kenly & Company, manufacturers of a variety of Simplex-Jacks, since 1899, offer a special Pipe-Pushing Jack which can be used for installing water or sewer service lines by pushing through iron or steel pipe as large as 4 inch diameter. As a "puller" it is especially useful in replacing old services with new flexible copper-tubing, now much in demand. The net result is less digging and labor, the minimizing of lawn damage and pavement repair, less traffic obstruction; and, less cost for the job.

Features of the Simplex Pipe Pusher: Operated by one to four men (twin jack principle), only three piece construction, tapered positive grip-jaws that are easily replaceable, fits in a hole 32x50 inches, has carriage travel of 27 inches at a single gripping.

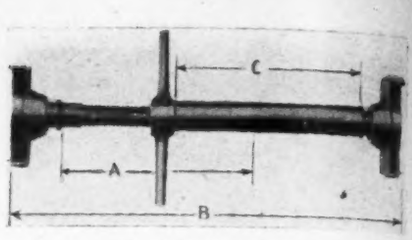
For illustrated bulletin, address Templeton, Kenly & Co., 1020 S. Central Ave., Chicago, Ill., or Graybar Building, New York City.

▼

Improved Trench Brace

An improved "Anchor" Steel Trench Brace has been announced by the Edelblute Manufacturing Company of Reynoldsville, Pa.

The old-style trench brace, being somewhat "weak-kneed" in respect to the pipe section, which was the first part to fail or bend badly, has been improved by adaptation of a new tubing of special carbon steel which is practically double the stiffness of pipe previously employed. The screw-bar is of special Bessemer threading steel and the brace-fittings are of



Steel Trench Brace

heavier certified malleable iron. The lever-nut, made more sturdy, provides quick adjustment and a three way lever nut is provided for work in close quarters.

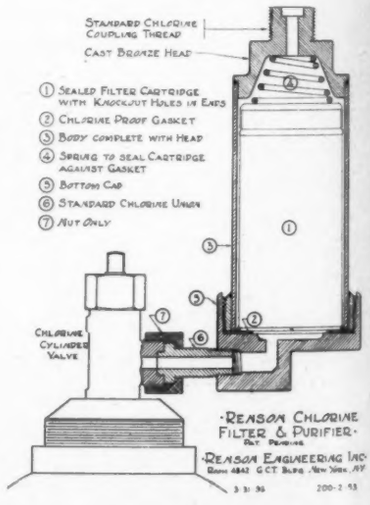
An illustrated leaflet showing styles, sizes and specifications can be had by addressing Edelblute Manufacturing Co., Reynoldsville, Pa.

▼

Renson Chlorine Filter

Renson Engineering, Inc., of New York City, announce a new device for removing gummy substances from chlorine gas. Although there may be only 1/100th per cent of impurities in liquid chlorine this is often sufficient to create obstruction of needle valves and small orifices of chlorinating equipment, or to coat the inside of glass equipment. To preclude this nuisance producing feature of chlorination and eliminate the frequent cleaning of chlorinating equipment, the Renson Purifier and Filter is offered.

The Renson Chlorine Gas Filter is claimed by its producer, having had 20 years' experience with chlorine problems, to effectively remove all troublesome impurities known to exist in liquid chlorine. One cartridge will, they claim, serve to purify 3 tons of chlorine containing the average impurities. The economy expected lies in reduced equipment maintenance expense. For more exact details, including guarantees and prices, address—Renson Engineering, Inc. (Dept. CHL), 4842 Grand Central Terminal, New York City.


STANDARD CHLORINE COUPLING THREAD
CAST BRONZE HEAD
① SEALED FILTER CARTRIDGE WITH KNOCKOUT HOLES IN ENDS
② CHLORINE PROOF GASKET
③ BODY COMPLETE WITH HEAD
④ SPRING TO SEAL CARTRIDGE AGAINST GASKET
⑤ BOTTOM CAP
⑥ STANDARD CHLORINE UNION
⑦ NUT ONLY
CHLORINE CYLINDER VALVE
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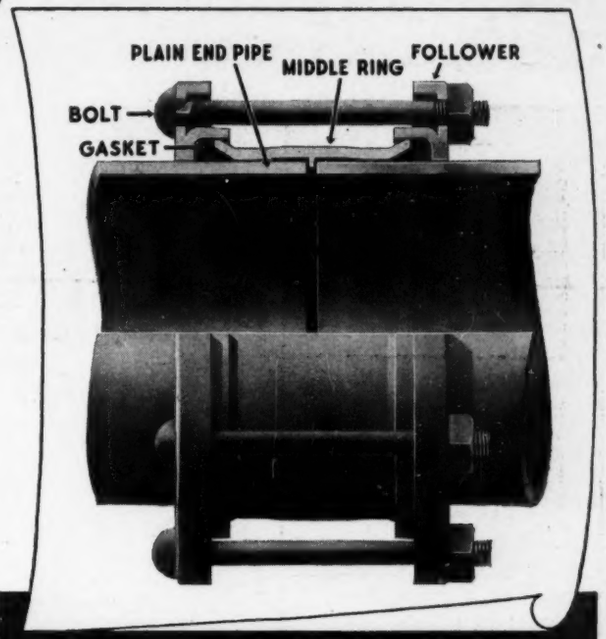
HOW THE DRESSER JOINT WORKS

...and what it means to YOU!



How the Dresser Joint Works. Standard, *factory-built* parts (see illustration) are simply assembled on the job over *plain* pipe-ends. As the bolts are tightened, two *resilient* gaskets are compressed around the pipe with a powerful packing force, assuring an *absolutely* tight seal under all conditions. This *proved* packing principle—a Dresser advantage for nearly fifty years—allows the pipe to deflect, expand, contract, or vibrate ... without leakage, or harm to the pipe or joint.

What This Means to You. Your piping problems are simplified. Only one tool—a wrench—is needed; ordinary labor is used. Chances of human error are completely eliminated. *Most important*—you save on joint-installation and -operating costs!

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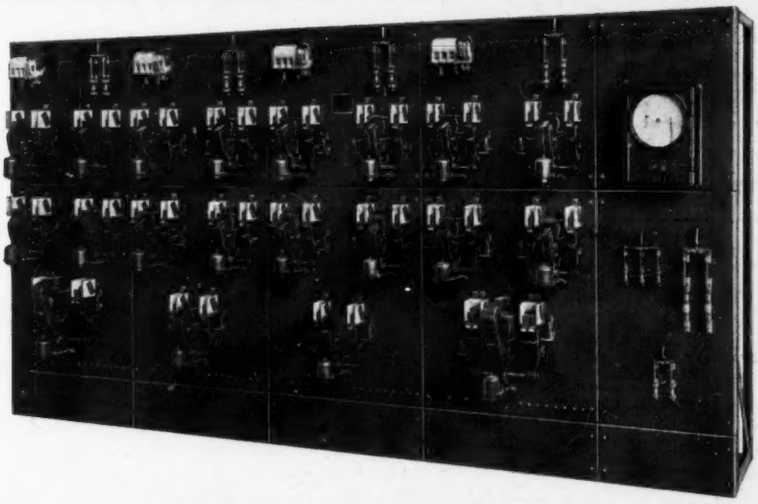
In Canada: Dresser Mfg. Company, Ltd.
32 Front St., W., Toronto, Ont.

DRESSER COUPLINGS

Clark-Sundh



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This department has been started as a service to those in the Water Works and Sewerage Fields. We hope they will make use of it. The notices are inserted without charge.

SALES ENGINEER, experienced with established office, Architects Building, Philadelphia, desires additional representation mechanical line for sewage disposal and equipment for swimming pools. References. J. W., % Water Works and Sewerage, 400 W. Madison St., Chicago, Ill.

GRADUATE ENGINEER: Civil Engineer (B. S. Yale University 1933) wishes position with construction or engineering firm. Experience since 1927 includes construction of steel frame buildings, highways, cost control work, geodetic surveys. Especially interested in work in sanitary field. Age 26, married. Address "E. V. T.," care WATER WORKS AND SEWERAGE, 155 East 44th Street, New York City.

SUPERINTENDENT or Chief Operator in small or medium sized plant or operator in large sized plant; 10 years' experience in water works field, last four in active charge of small rapid sand filter plant; 23 years' electrical experience in generation, distribution and maintenance. Now employed, married, 43 years of age. Can furnish references. Address L. A. B., Water Works & Sewerage, 400 W. Madison St., Chicago, Ill.

SALES ENGINEER—Graduate Registered Professional Engineer, now employed, desires regular sales position with manufacturing concern specializing in machinery and equipment for construction of sewage disposal plants and kindred fields. 15 years in sales and sanitary experience in this work. Age 41; married; best of references, will go anywhere. Address H. T. C., % Water Works & Sewerage, 155 East 44th St., New York City.

OPERATOR OF PUMPS, powered by electric motor, gas engine or Diesel engine; also can take care of and read water meters. I am a married man and can give good references. Address R. A. M., Water Works & Sewerage, 400 W. Madison St., Chicago, Ill.

POSITION WANTED — As superintendent filtration, chemist and bacteriologist, or operator chemist and bacteriologist, of small or medium sized plant, by young man technically educated, industrious and ambitious for plant betterment. Eleven years' experience. May I have the opportunity of communicating with you? Address J. Z. C., % Water Works & Sewerage, 400 W. Madison St., Chicago.

SANITARY ENGINEER-CHEMIST: Graduate Sanitary Engineer, (M. S. degree) with eight years' experience in water works and sewerage operation; and analysis of water and sewage. Wants operating position in water works or sewerage field; preferably in Southern states. Age 30, married and now employed. Address A. U., % WATER WORKS AND SEWERAGE, 155 East 44th St., N. Y. C.

CHEMICAL AND SANITARY ENGINEER: 30, married. M.I.T. graduate. Nine years' local and foreign experience. Design, construction and operation of public and industrial water purification plants. Iron removal. Waste disposal. Bacteriologist. Good record, excellent references. Now employed. Location immaterial. Address J. E. K., Water Works & Sewerage, 155 East 44th St., N. Y. C.

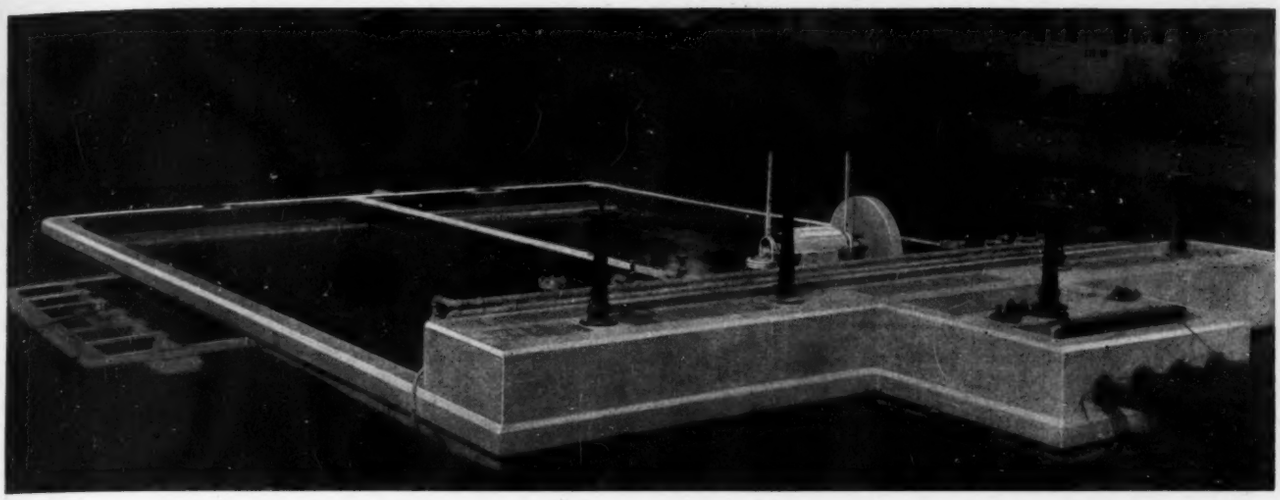
CIVIL ENGINEER: 1935 graduate of Cornell University, degree of C. E. Desires experience, salary or location immaterial. Age 22. Address R. W. M., % Water Works and Sewerage, 155 East 44th St., New York City.

GRADUATE MECHANICAL ENGINEER: Two degrees. Thirty-one years of age, married. Seven years' experience in water works construction and management. Past two years as Supt. of Water Works in a city of 70,000. References as to character and ability furnished upon request. Available immediately. Address "R. P.," Water Works and Sewerage, 155 East 44th Street, New York, N. Y.

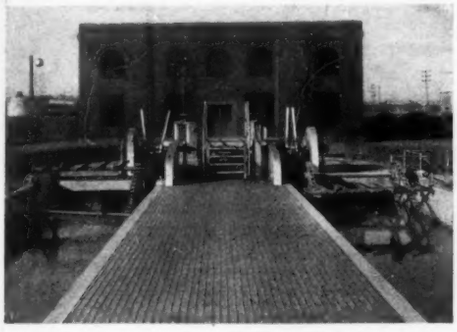
SANITARY ENGINEER. Age 25. Married. M. S. to be received in June from U. of Illinois. Research Assistant in sewage research (garbage and sludge digestion) for the past two years. One year experience in State Highway Office making cost computations on Federal Aid work. Interested in any position in sanitary engineering. Location immaterial. "F. H. W.," Water Works & Sewerage, 400 W. Madison St., Chicago, Ill.

SANITARY ENGINEER—Will receive M. S. in Sanitary Engineering, June, 1936. Engaged since March, 1934, as Research Assistant in Sewage Treatment at University of Illinois. Had responsible management of Sewage Testing Plant and Laboratory. Age 24, married. "B. J. L.," Water Works & Sewerage, 400 W. Madison St., Chicago, Ill.

STRAIGHTLINE EQUIPMENT
—for Positive Results and High Efficiency



Primary settling tanks at Collingswood, N. J., equipped with Link-Belt Straightline collectors. High efficiency, long life, low maintenance and positive removal of sludge, make the Straightline collector the preferred unit for removing sludge from settling tanks. Send for Book No. 1542.



The Link-Belt Straightline grit collector and washer was developed to collect the settled grit, and to wash it free from putrescible organic matter. This unit consists of a settling tank provided with a scraper-type collector; and an inclined washing and dewatering screw to which the collector conveys and discharges the grit at bottom of tank. For smaller installations the Link-Belt Tritor screen is the ideal machine.

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GRIT CHAMBER EQUIPMENT
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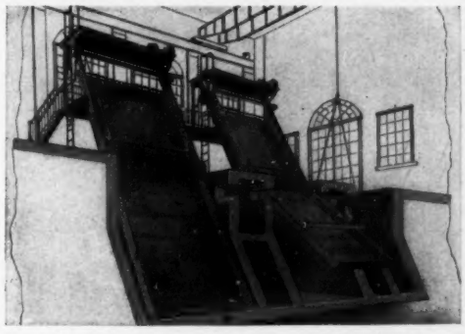

Link - Belt Straightline mechanically cleaned bar screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants. Send for Book No. 1587.

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On other pages in this issue you will find described new and improved equipment, etc., as well as reviews of recent trade literature received by us. By requesting the literature described you will be able to keep your catalog file complete and up to date.

To our readers desiring additional help or information we will be glad to assist you in securing more complete information or data on any equipment or product you need. Use the convenient blank below —no cost or obligation.

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The record of the meter is *not* interrupted. No batteries.

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Sewage Plant Construction

Remember, when you are planning your new sewage plant, swimming pool or in fact any type of concrete structure, that the life of that structure depends on the joint filler you employ.

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Your plant may be worth millions, yet the cost of enclosing it with Pittsburgh Chain-Link Fence is a comparative trifle. Years after it has been erected, it will still be standing, still giving faultless service. We will be glad to give you an estimate on fencing your property.

PITTSBURGH STEEL CO.
754 UNION TRUST BUILDING
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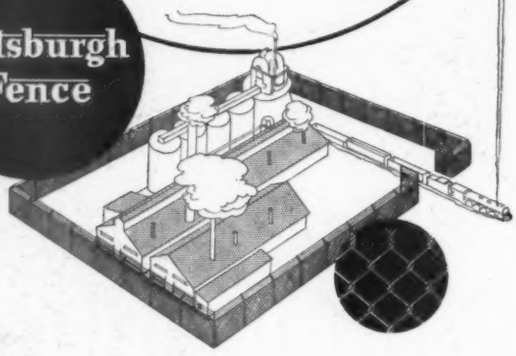
Pittsburgh Fence



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Barber-Greene's Superior features: the Vertical Boom, Milling Action digging, Automatic Overload Release, Self-Cleaning Buckets and many others give profitable digging. They bring results like 7c a foot for a Washington Water Department (partly through hardpan) . . . 5c a foot for a Texas Gas Company . . . 2½c a foot for hundreds of miles of pipe-line trench. Send a card for "Ditching Snapshots and Records." There is no obligation.

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Use Sika to stop the inflow of water through dams, walls of pump houses, man-holes, filter beds, sewage tunnels, etc. Sika mixed with portland cement is easily applied by hand and will successfully seal off infiltration from underground streams even under pressure.

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Anthrafilt beds need not be deeper than sand beds but the lighter weight (55 against 100) permits a deeper bed, ensuring greater efficiency and longer runs.

Since Anthrafilt does not require as much supporting gravel as sand, additional bed depth can be secured by removing some of the gravel.

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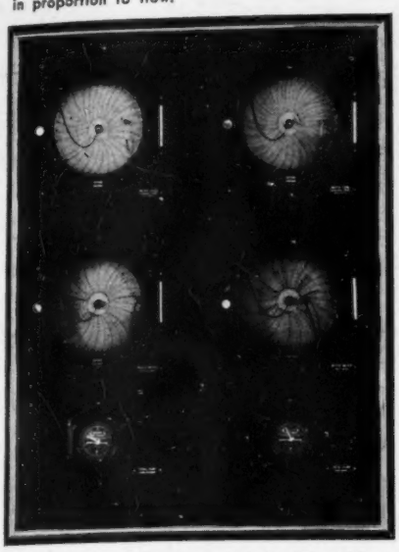
A. W. W. A. Booths 17-18

Builders men will be in Booth 17 and 18 ready to display and discuss the latest Venturi developments: a new Venturi Register-Indicator-Recorder; equipment for metering and controlling nearby or distant flows, elevated tank or reservoir levels, and gate and valve positions; new designs for sewage meters; and %Proportioneers% devices for accurately feeding chlorine or other chemicals in proportion to flow.



Chronoflo Panel Board at Orinda Filter Plant, East Bay Municipal Utilities District, Oakland, California. Chronoflo Instruments shown: Record water level at East Portal of Claremont Tunnel; at West Portal of Claremont Tunnel; record and totalize filter effluent; and record and totalize wash water flow.

West or East "Builders" Means Up-to-the-Minute Water Works Metering and Controlling Equipment

At Los Angeles, Water Works men from east, west, north, and south will rub shoulders, sharing with each other experiences in the furnishing of potable drinking water to America.

From whatever state they come, they will have in common a knowledge of Venturi Metering and Controlling equipment which "Builders" has furnished to help them operate their plants more efficiently.

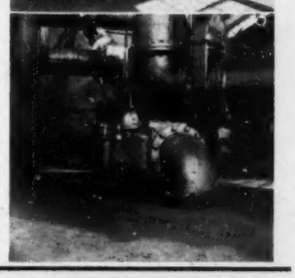
Illustrations on this page show some installations of late developments of Builders equipment—installed (above) at East Bay, Orinda, California, and (at left) at Brawley, California. Among many other west coast installations in successful operation are—San Francisco, Portland, Seattle, Morris (Pine Canyon) Dam, and a group of large penstock Venturi Meters installed by Southern California Edison.

If unable to attend the convention, write for information.

BUILDERS IRON FOUNDRY

9 Codding St. Providence, R. I.

(Below) Three views of Brawley, California, Filtration Plant, where five Venturi Direct-Acting Controllers and a Chronoflo Register-Indicator-Recorder are installed.



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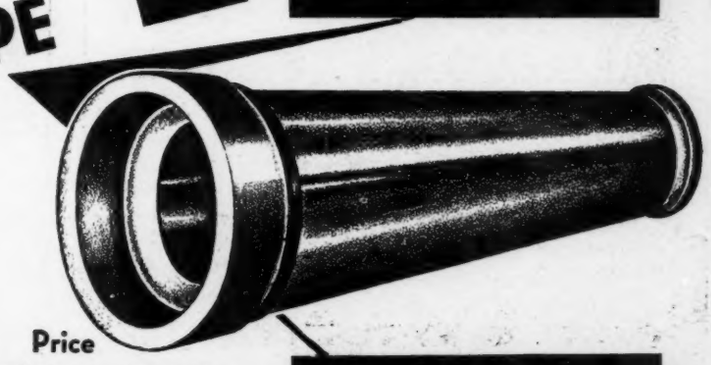
BELL & SPIGOT
Class A
Standard 12-foot joints
Weight, 4250 lbs. per joint
Amount, 5000 tons



This pipe was purchased new in 1917. It has been passed on by the Pittsburg Testing Laboratories and stands hydrostatic test. Complete with valves and fittings. Available in any quantity. Write for descriptive photographs and copy of Pittsburg Laboratories preliminary inspection report.

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Valves and Fittings Included

48-INCH
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Standard 12-foot joints
Weight, 8000 lbs. per joint
Amount, 5000 tons

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SANTOSITE—An efficient and economical reducing agent for removing dissolved oxygen

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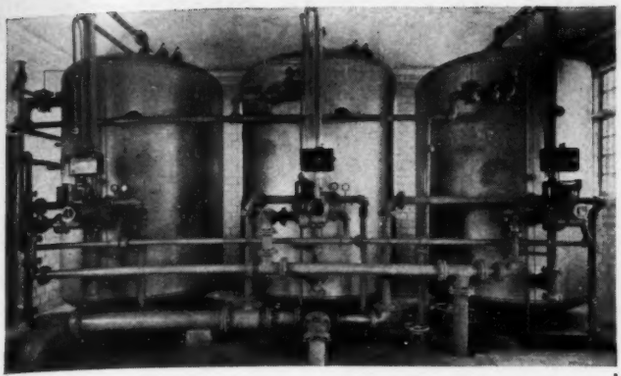

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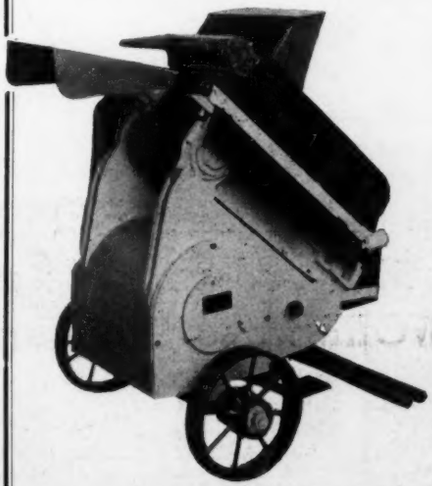

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Smallest Diaphram Pump Made. 2" Suction Open Discharge. Capacity 1400 G.P.H. Weight 50 lbs.
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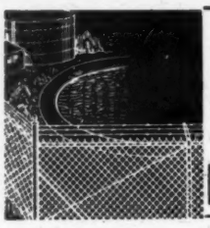

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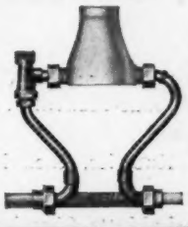

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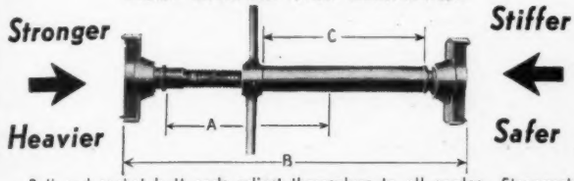

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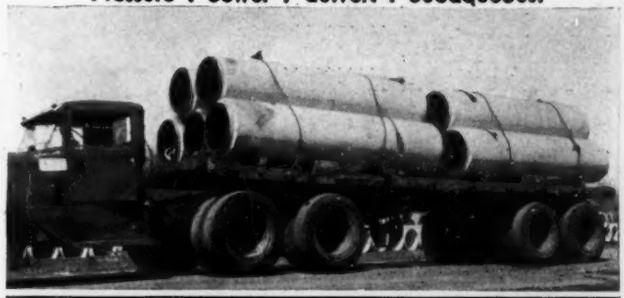

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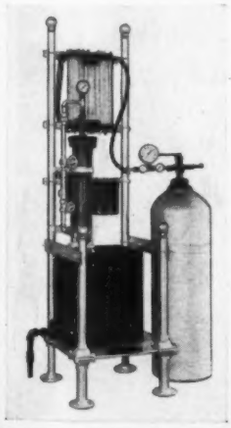

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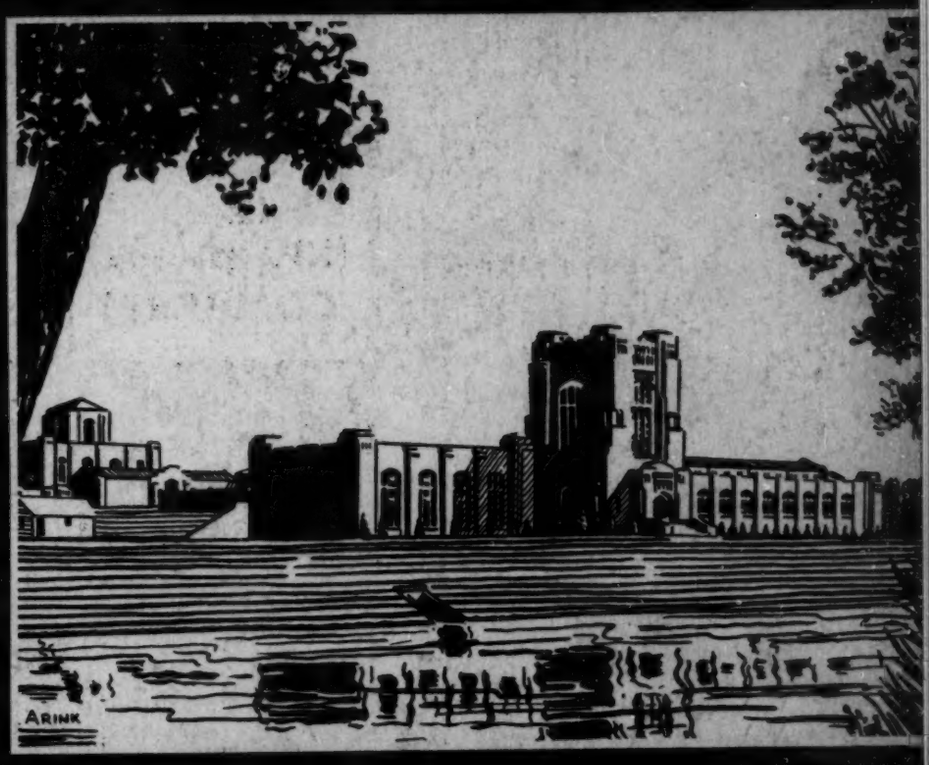
WATER WORKS
& SEWERAGE



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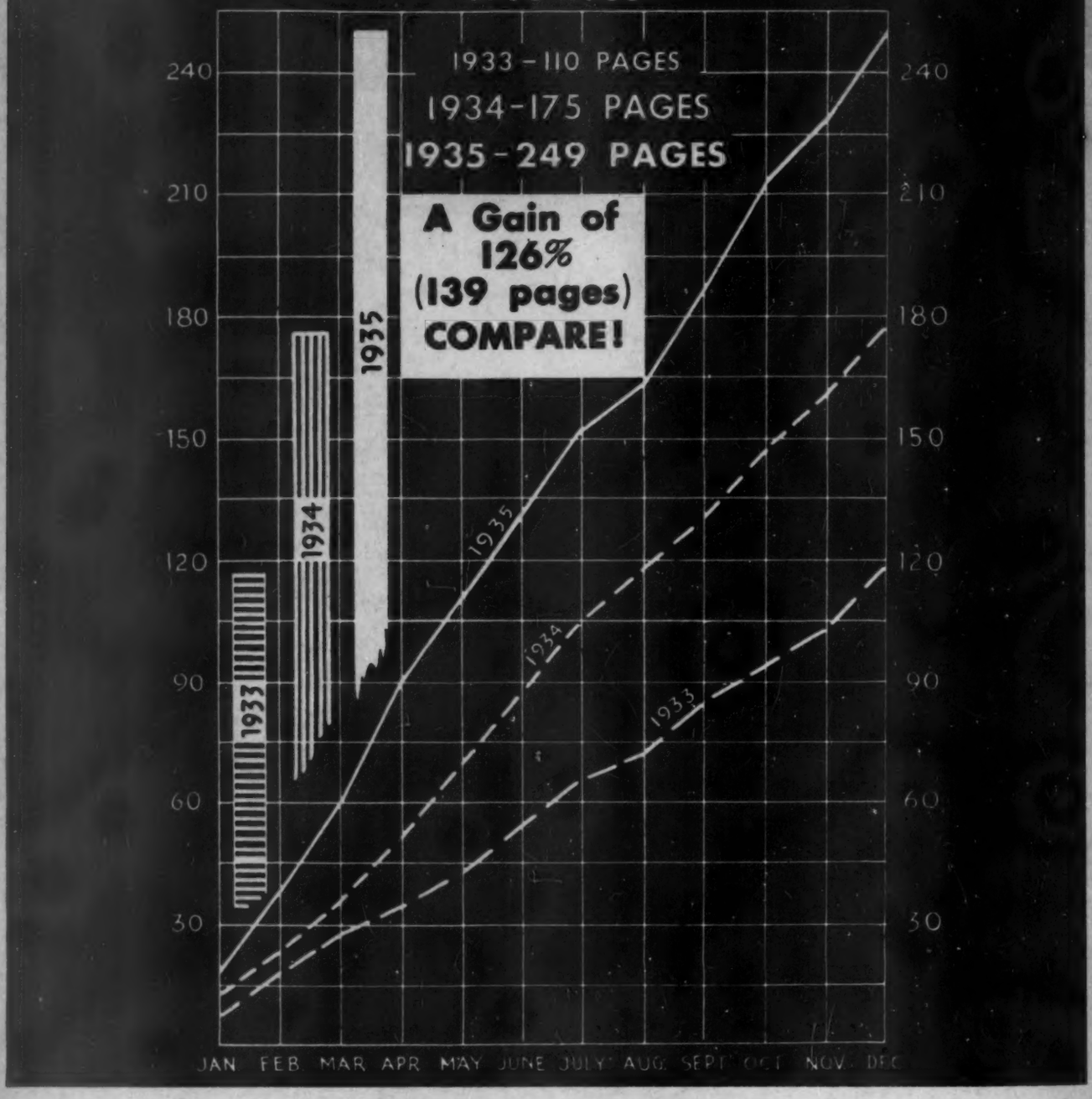

First 5 Issues of 1935 Carried 113 pages
First 5 Issues of 1936 Carried 168 pages

Average gain of 11 pages per issue over 1935

The 17 issues, January 1935 to May 1936, have carried advertising for 118 different manufacturers of Water Works and Sewerage materials and equipment. 103 manufacturers are represented in this May issue.

WATER WORKS & SEWERAGE

400 West Madison Street, Chicago **155 East 44th Street, New York**

FOREWORD

GILLETTE PUBLISHING COMPANY presents herewith the Reference and Data Number of WATER WORKS AND SEWERAGE.

This section has been prepared by Mr. L. H. Enslow, Editor of Water Works and Sewerage, and gives the equivalent of a 432-page handbook of data on the design, construction, operation and maintenance of waterworks and sewerage.

The contents are carefully selected matter from the files of Water Works and Sewerage and from other sources named in the text. In addition, scores of letters have been written to secure the latest hydraulic tables and standards and the most economical methods. In a word, the same conscientious work has been put into the writing of the section as would be expected in a book devoted exclusively to this purpose.

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ABRASIVES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

ACID, HYDROCHLORIC
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACID, SULPHURIC
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

ACTIVATED CARBON
Cliffs-Dow Chemical Co., Marquette, Mich.
Industrial Chemical Sales Co., 230 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

ACTIVATED SLUDGE PLANTS
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.

AERATION APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service, 155 E. 44th St., N. Y. C.
Permutit Co., 330 W. 42nd St., N. Y. C.
Simplex Valve & Meter Co., 68th and Upland, Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

ALLOY BODIED VALVES
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

ALLOY CAST IRON PIPE & FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

ALUM, AMMONIA
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, FILTER, COMMERCIAL, IRON FREE
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUMINUM SULFATE
Merrimac Chemical Co., Boston, Mass.
Penn. Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Everson Mfg. Co., 627 W. Lake St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Elmer & Amend, 18th and 3rd Ave., New York City.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.

ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

ASBESTOS-CEMENT PIPE
Elmer & Amend, 18th and 3rd Ave., New York City.
Johns-Manville, 22 E. 40th St., New York City.

ASH & COAL HANDLING MACHINERY
Combustion Engrg. Co., 200 Madison Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Company, 400 No. Lexington Ave., Pittsburgh, Pa.

ASPIRATORS
Vogt Mfg. Co., Louisville, Ky.

AUTOMATIC FILTER AND SOFTENER CONTROLS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.

BEARINGS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BELTS, SEWER PIPE
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

BINS, STEEL
Blaw-Knox Company, Pittsburgh, Pa.
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BINS, STORAGE
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

BLEACHING POWDER
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

BOILER FEED PUMP CONTROL
Automatic Primer Co., 113 W. Washington St., Chicago, Ill.

BOILER FEEDWATER TREATMENT
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
Merrimac Chem. Co., Boston, Mass.
Natl. Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

BOILER PLANT ACCESSORIES
Permutit Co., 330 W. 42nd St., New York City.
So. Bend Foundry Co., So. Bend, Ind.

BOILERS, GAS
American Gas Prod. Corp., 40 W. 40th St., New York City.

BOILERS, STEAM
Combustion Engrg. Co., 200 Madison Ave., New York City.

BOILER WATER PURIFICATION APPARATUS
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BOXES, VALVES, ROADWAY, MITER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

BRACES, TRENCH, EXCAVATION
Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

BREECHINGS, STEEL
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKET LOADERS
Barber Greene Co., Aurora, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BUCKETS, DREDGING & EXCAVATING
Blaw-Knox Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.

CALCIUM HYPOCHLORITE
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CALKING MACHINES AND TOOLS
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS
Carborundum Co., Niagara Falls, N. Y.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CASINGS & COVERINGS, STEAM PIPE
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
A. Wyckoff & Son Co., Elmira, N. Y.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Blaw-Knox Co., Pittsburgh, Pa.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
So. Bend Foundry Co., So. Bend, Ind.

CASTINGS, MUNICIPAL
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
So. Bend Foundry Co., So. Bend, Ind.
U. S. Pipe & Foundry, Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CASTINGS, SPECIAL
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CATCH BASINS, CORRUGATED IRON
Armco Culvert Mfrs. Assn., Middletown, Ohio.

CAUSTIC SODA
Belle Alkali Co., Charlestown, W. Va.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener bldg., Philadelphia, Pa.

CEMENT
Portland Cement Assn., 133 W. Grand Ave., Chicago, Ill.

CENTRIFUGE EQUIPMENT
Amer. Centrifugal Corp., 115 Broadway, New York City.

CHAINS, CONVEYOR
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CHEMICAL FEEDING EQUIPMENT
Everson Mfg. Co., 627 W. Lake St., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Omega Mach. Co., 602 Westport Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, 110 W. Washington St., Buffalo, N. Y.

CHEMICAL PROPORTIONEERS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHIMNEYS
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CHLORIDE, FERRIC
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINATORS
Everson Filter Co., 633 W. Lake St., Chicago, Ill.
Filcior Co., 59th & Upland Sts., Philadelphia, Pa.
Filtration & Water Softening Pty. Ltd., Melbourne, Australia.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID
Belle Alkali Co., Charlestown, W. Va.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chem. Co., St. Louis, Mo.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINE CONTROL EQUIPMENT
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Rascher & Betzold, Inc., 829 Orleans St., Chicago, Ill.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, STEEL & COAL
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES
Amer. Cast Iron Pipe Co., Birmingham, Ala.
S. R. Dresser Mfg. Co., Bradford, Pa.

CLAMPS AND SLEEVES—RIVER
S. R. Dresser Mfg. Co., Bradford, Pa.

CLARIFIERS, SEWERAGE AND WATER
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CLOROBEN
Cloroben Corp., 90 Forrest Ave., Jersey City, N. J.

COAGULATING EQUIPMENT
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

COAL ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Inertol Co., Inc., 401 Broadway, New York City.

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COLLECTORS
Blaw-Knox Co., Pittsburgh, Pa.
Dorr Co., 247 Park Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATOR
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
La Motte Chem Prod. Co., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPRESSORS, AIR
Fuller Co., Catasauqua, Pa.

COMPOUNDS, SEWER
Atlas Mineral Prod., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

CONCRETE BREAKERS
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CONDENSERS
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.

CONTROLLERS, FLOW, LEVEL, PRESSURE, RATIO, TEMPERATURE
Automatic Primer Pump Co., 113 W. Washington St., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

CONVEYORS AND CONVEYING EQUIPMENT
Barber-Greene Co., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Combustion Engrg. Co., 200 Madison Ave., New York City.
Dracco Corp., Cleveland Ohio.
Fuller Co., Catasauqua, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CONVEYORS—VIBRATORY—ELECTRIC
Jeffrey Mfg. Co., Columbus, Ohio.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

COPPER AND BRASS
American Brass Co., Waterbury, Conn.

COUPLINGS & CONNECTIONS, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill.

COVERINGS, UNDERGROUND, WOODEN
A. Wyckoff & Son Co., Elmira, N. Y.

CRANES
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CRUSHING MACHINERY
Gruendler Crusher & Pulverizer Co., Dept. S., N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.

CULVERTS
Amer. Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron).
R. D. Wood Co., Philadelphia, Pa.

DECHLORINATORS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

DIAPHRAGMS, PUMP
Dorr Co., 247 Park Ave., New York City.
Edson Corp., 49 D St., So. Boston, Mass.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

DIFFUSERS—PLATES & TUBES
Carborundum Co., Niagara Falls, N. Y.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Norton Co., Worcester, Mass.

DIGESTERS, SLUDGE
Dorr Co., 247 Park Ave., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS
Dorr Co., 247 Park Ave., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts, Philadelphia, Pa.

DITCHERS AND TRENCHERS
Barber-Greene Co., Aurora, Ill.

DRAINS, STORM
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Lock Joint Pipe Co., Ampere, N. J.
R. D. Wood Co., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Syntron Co., 400 N. Lexington St., Pittsburgh, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

DRYERS
Combustion Engrg. Co., 200 Madison Ave., New York City.
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Nichols Eng. and Research Corp., 40 Wall St., New York City.

DRYERS, ROTARY
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

DRYERS, SAND PORTABLE
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

DRYERS—SPRAY
Bowen Research Corp., Garwood, N. J.

EDUCATORS
Vogt Mfg. Co., Louisville, Ky.

ELEVATING & CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINES, DIESEL
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Fairbanks-Morse Co., 900 So. Wabash Ave., Chicago, Ill.

EXCAVATORS, DITCH & TRENCH
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEEDERS, ROTARY
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

FENCING (IRON PICKET & CHAIN LINK WIRE)
Pittsburgh Steel Co., Union Trust Bldg., Pittsburgh, Pa.
Stewart Iron Wks. Co., Cincinnati, Ohio.

FERRIC CHLORIDE, LIQUID & ANHYDROUS
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid.)

FERRIC CHLORIDE FEEDERS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC SULFATE
Merrimac Chemical Co., Boston, Mass.

FERRIC SULPHATE FEEDERS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

FILTERING EQUIPMENT
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 627 W. Lake St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
Filtration & Water Softening Pty. Ltd., Melbourne, Australia.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Sanitary Service, 155 E. 44th St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts. Philadelphia, Pa.

FILTER PLATES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

FILTERS, GRAVITY & PRESSURE
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

FILTER STRAINERS & NOZZLES
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

FILTERS, VACUUM
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

FILTER UNDERDRAINS
Carborundum Co., Niagara Falls, N. Y.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.

FLASH MIXERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Vogt Mfg. Co., Louisville, Ky.

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

FLOOR GRATING
Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.

FLOORING, INDUSTRIAL
Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
R. D. Wood Co., Philadelphia, Pa.

FLOW RECORDERS
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

FLOW REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
McNulty Engr. Co., So. Boston, Mass.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D. St., So. Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood, Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
L. A. Weston, Adams, Mass.

FORMS, CONCRETE
Blaw-Knox Co., Pittsburgh, Pa.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products, Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.

GARBAGE DISPOSAL APPARATUS
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 247 Park Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS FIRED EQUIPMENT, RADIATORS, HEATERS, STORAGE HEATERS, AIR CONDITIONERS, ETC.
American Gas Prod. Corp., 40 W. 40th St., New York City.
Mueller Co., Decatur, Ill.

GAS HOLDERS
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PRODUCERS, AUTOMATIC
R. D. Wood Co., Philadelphia, Pa.

GATES, DRAINAGE
Armco Culvert Mfrs. Assn., Middletown, Ohio.
McNulty Engrg. Co., 200 Old Colony Ave., Boston, Mass.

GATES, IRON PICKET & CHAIN LINK WIRE
Stewart Iron Wks. Co., Cincinnati, Ohio.

GATES, ROTARY DISCHARGE
Fuller Co., Catasauqua, Pa.

GATES, SLUICE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
McNulty Engrg. Co., 200 Old Colony Ave., Boston, Mass.

GATE VALVE HOUSING
Ludlow Valve Mfg. Co., Troy, N. Y.

GAUGES, LIQUID LEVEL, PRESSURE, RECORDING
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders' Iron Foundry, Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

GENERATORS, SETS, ELECERIC & DIESEL ENGINES
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Fairbanks-Morse Co., 900 S. Wabash Ave., Chicago, Ill.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

GOOSENECKS
Mueller Co., Decatur, Ill.

GRATINGS, FLOORINGS
Arrowhead Iron Wks., Kansas City, Mo.
Blaw-Knox Co., Pittsburgh, Pa.

GRAY IRON CASTINGS
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
So. Bend Foundry, So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

GRINDERS
Dorr Co., 247 Park Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Norton Co., Worcester, Mass.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

GRINDING WHEELS
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

GRIT CHAMBER EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HAMMERS, CAULKING, CHIPPING
Hydraulic Development Corp., 50 Church St., New York City.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

HOPPERS, STEEL
Chicago Bridge & Iron Wks., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

HOSE, STEAM, AIR, WATER, SUCTION
Edson Corp., 49 D St., So. Boston, Mass.

HYDRANT PROTECTORS
Edson Corp., 49 D St., So. Boston, Mass.

HYDRANTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULIC MACHINERY
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULIC TRANSFER SWITCHES
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.

HYDRAULIC VALVE CONTROLS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. D. Wood Co., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Co., Baltimore, Md.
Permutit Co., 330 W. 42nd St., New York City.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.

HYPO-CHLORINATORS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

INCINERATORS
Combustion Engr. Co., 200 Madison Ave., New York City.
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Morse-Boulger Destructor Co., 205 E. 44th St., New York City.
Municipal Sanitary Service, 155 E. 44th St., New York City.
Nichols Engr., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATORS, CHEMICAL
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Builders Iron Foundry, 9 Codding St., Providence, R. I.

INSTRUMENTS, FLOW RECORDING, TROUBLE FINDING
Brainard & Hatch, 246 Palm St., Hartford, Conn.

IRON & MANGANESE REMOVAL PLANTS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

IRON SALTS IN SEWAGE TREATMENT
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.

JACKS, MECHANICAL & SCREW
Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., Inc., 1020 S. Central Ave., Chicago, Ill.

JACKS, PULLING
Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly Co., 1020, S. Central Ave., Chicago, Ill.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Co., 50 Church St., New York City.

JOINTS, EXPANSION
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Johns-Manville, 22 E. 40th St., New York City.
Lock-Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
Servicised Prod. Co., 6051 W. 65th St., Chicago, Ill.

JOINTS, FILLER
Inertol Co., 401 Broadway, New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

JOINTS, MECHANICAL
Amer. Cast Iron Pipe Co., Birmingham, Ala.
S. R. Dresser Mfg. Co., Bradford, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Elmer & Amend, 18th & 3rd Ave., New York City.
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Phipps & Bird, 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

LABORATORY WARE
Carborundum Co., Niagara Falls, N. Y.
Elmer & Amend, 18th and Third Ave., New York City.
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.

LIME SLAKERS
Chicago Bridge & Iron Wks., 37 W. Van Buren St., Chicago, Ill.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.

LINERS, ASPHALT SEWER
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LOADERS, GRAVEL, WAGON, CAR, ETC.
Barber-Greene Co., Aurora, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

LUBRICATORS, FORCE FEED
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METALS—CORROSION RESISTING
Amer. Brass Co., Waterbury, Conn.

METER ACCESSORIES, BOXES, HOUSINGS, ETC.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER-MASTER
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

METERS, GAS
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, PITOT
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTERS
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.

METER TESTING TANKS
Ford Meter Co., Wabash, Ind.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, WATER AND SEWAGE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

MIXERS, CHEMICAL
Dorr Co., 247 Park Ave., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

MIXING BASIN EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 247 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chain Belt Co., Milwaukee, Wis.
Pacific Flush Tank Co., 4241 N. Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ODOR CONTROL
Cloroben Corp., 90 Forest St., Jersey City, N. J.

OPERATING TABLES
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Proportioneers, 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PACKING, RAWHIDE
Chicago Rawhide Mfg. Co., 1283 Elston Ave., Chicago, Ill.

PAVING ASPHALT BRIDGE PLANKS
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PENSTOCKS
Chicago Bridge and Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH EQUIPMENT
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan, Inc., Newark, N. J. (automatic).
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PIPE AND TANK COATINGS
Inertol Co., Inc., 401 Broadway, New York City.

PIPE, ACID PROOF FOR CHEMICAL LINES
American Cast Iron Pipe Co., Birmingham, Ala.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
Sonken-Galamba Corp., 64 N. 2nd St., Kansas City, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, COMMERCIAL O. D. WITH THREADED JOINTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Steel Co., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, CONCRETE
Lockjoint Pipe Co., Ampere, N. J.

PIPE CONNECTIONS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CORRUGATED
American Rolling Mill Co., Middletown, Ohio.
Armco Culvert Mfrs. Assn., Middletown, Ohio.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill.
Sonken-Galamba Corp., 64 N. 2nd St., Kansas City, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE JOINT COMPOUNDS
Atlas Mineral Products, Mertztown, Pa.
Hydraulic Development Co., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PIPE JOINT TOOLS
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PIPE LOCATORS
Engineering Research Corp., 325 Giddens-Lane Bldg., Shreveport, La.

PIPE PUSHERS
Templeton, Kenly Co., 1020 S. Central Ave., Chicago, Ill.

PIPE RAILING
Stewart Iron Works, Cincinnati, Ohio.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
Lock Joint Pipe Co., Ampere, N. J.

PIPE TAPPING MACHINES
Mueller Co., Decatur, Ill.

PIPE, WELDED STEEL
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE WITH SPECIAL LININGS
American Cast Iron Pipe Co., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, WOOD
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, WROUGHT IRON
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Reading Iron Co., Philadelphia, Pa.

PITOT TUBES
Builders Iron Foundry Co., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PLANTS, CHEMICAL TREATING
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

PLANTS, MUNICIPAL FILTRATION
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Co., Darby, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

POURING GATES
Hydraulic Development Corp., 50 Church St., New York City.

POWER TRANSMISSION MACHINERY
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

PROPORTIONING EQUIPMENT
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PROTECTION COURSE FOR WATERPROOFING
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PUMP PRIMERS
Automatic Primer Co., 113 W. Washington St., Chicago, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.

PUMPS, AIR LIFT
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, BOILER FEED
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Corp., 3431 W. 48th Pl., Chicago, Ill.

PUMPS, CENTRIFUGAL
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, CENTRIFUGAL AND MULTI-STAGE HIGH LIFT
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Co., 3431 W. 48th Pl., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, CHEMICAL, PROPORTIONING
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PUMPS, CIRCULATING
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.

PUMPS, DIAPHRAGM
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, NON-CLOG
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pump Machinery Co., 3431 W. 48th Pl., Chicago, Ill.

PUMPS, ROTARY
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, SCREW FEED CENTRIFUGAL
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

PUMPS, SEWAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Novo Engine Co., Lansing, Mich.

PUMPS, SLUDGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PUMPS, SUCTION AND FORCE
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, SUMP
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.

PUMPS, TRIPLEX
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, TURBINE
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

PUMPS, VACUUM
Barrett-Haentjens & Co., Hazleton, Pa.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Elmer & Amend, 3rd Ave. and 18th St., New York City.
Fuller Co., Catasauqua, Pa.

PUMPS, WATER SEAL
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.

PUSH AND PULL JACKS
E. Delblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly Co., 1020 S. Central Ave., Chicago, Ill.

RATE OF FLOW CONTROLLERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

RECEIVERS, AIR
Chicago Bridge & Iron Works, 2198 Old Colony Bld., Chicago, Ill.

REDUCTION MACHINERY
Jeffrey Manufacturing Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

REFRACTORIES
Carborundum Co., Niagara Falls, N. Y.
Johns-Manville, 22 E. 40 St., New York City.
Norton Co., Worcester, Mass.

REFRACTORY CEMENTS
Carborundum Co., Niagara Falls, N. Y.
Johns-Manville, 22 E. 40 St., New York City.
Norton Co., Worcester, Mass.

REGULATORS, SEWER
McNulty Engineering Co., 200 Old Colony Ave., South Boston, Mass.

REGULATORS, WATER AND GAS
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

ROOFING
Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

RUBBER—ALL PURPOSES
United States Rubber Co., 1790 Broadway, New York City.

SADDLES, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.

SAMPLERS AND SAMPLING TABLES
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., Providence, R. I.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

SAND AND GRAVEL PLANTS
Dorr Co., 247 Park Ave., New York City.
Gruendler Crusher and Pulverizer Co., Dept. S, N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SAND FILTRATION
Everson Mfg. Co., 627 W. Lake St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SAWS—ELECTRIC, PORTABLE
Syntron, 400 N. Lexington Ave., Pittsburgh, Pa.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Lakeside Engr. Corp., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 247 Park Ave., New York City.
Gruendler Crusher and Pulverizer Co., Dept. S, N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Municipal Sanitary Service, 155 E. 44th St., New York City.

SCREENS, SEWAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Co., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service, 155 E. 44th St., New York City.

SELF-CAULKING PIPE JOINT COMPOUNDS
Atlas Mineral Prod., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

SEWAGE CLEANING BALLS, RUBBER
W. J. Voit Rubber Corp., P. O. Box 250, Arcade Station, Los Angeles, Calif.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SEWAGE SCREENINGS GRINDER
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Royer Foundry and Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Municipal Sanitary Corp., 155 E. 44th St., New York.
Nichols Engineering & Research Corp., 40 Wall St., New York City.

SEWAGE TREATMENT EQUIPMENT
Builders Iron Foundry Co., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 247 Park Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWERS, SANITARY
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

SIGNALS, BIN
Fuller Co., Catasauqua, Pa.

SIPHONS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, TAPPING (VALVE)
Ludlow Valve Mfg. Co., Troy, N. Y.
Vogt Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SLUDGE DEWATERING
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.

SLUDGE DISINTEGRATORS
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

SLUDGE PUMPS
Chain Belt Co., Milwaukee, Wis.

SLUDGE TESTING
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md. (pH and chlorine).

SODA ASH
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Works, 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM ALUMINATE
Merrimac Chemical Co., Boston, Mass.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM HYDROCHLORIDE
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Niagara Alkali Works, 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SPEED REDUCERS, TRANSMISSION
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SPRAY DRYING EQUIPMENT
Bowen Research Corp., Garwood, N. J.

SPRINKLING FILTER PLANTS
Dorr Co., 247 Park Ave., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

STACKS, FUME
A. Wyckoff & Son Co., Elmira, N. J.

STANDPIPE AND TANKS
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Columbia Steel Tank Co., Kansas City, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STEAM AND GAS PURIFIERS
Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

STEEL PLATE CONSTRUCTION
Blaw-Knox Co., Pittsburgh, Pa.
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STIRRERS
Dorr Co., 247 Park Ave., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

STOKERS
Combustion Engineering Co., 200 Madison Ave., New York City.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

STRAINERS, SUCTION
Barrett-Haentjens & Co., Hazleton, Pa.
Edson Corp., 49 D St., South Boston, Mass.

SWIMMING POOLS AND EQUIPMENT
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.

SWIMMING POOL PAINT IN COLORS
Inertol Co., Inc., 401 Broadway, New York City.

SWITCHES, FLOAT
Barrett-Haentjens & Co., Hazleton, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TAMPERS, TRENCH
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
R. D. Cole Co., Newnan, Ga.
Columbia Steel Tank Co., Kansas City, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANKS, SEDIMENTATION
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 247 Park Ave., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANKS, STEEL
(See Tanks, Elevated Steel)

TASTE AND ODOR REMOVAL EQUIPMENT
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

TESTERS, WATER METER
Ford Meter Box Co., Wabash, Ind.

THICKENERS
Dorr Co., 247 Park Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

TREADS, SAFETY
Arrowhead Iron Works, Kansas City, Mo.
Blaw-Knox Co., Pittsburgh, Pa.

TRENCH BRACES
(See Braces, Trench Excavating)

TURBINES, HYDRAULIC
S. Morgan Smith Co., York, Pa.

VACUUM HEATING PUMPS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

VALVE BOXES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE OPERATING PARTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

VALVES
Automatic Primer Co., 113 W. Washington St., Chicago, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy N. Y.
Mueller Co., Decatur, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHECK
Barrett-Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

VALVES, FLAP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

VALVES, FOOT
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.

VALVES, GATE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, MUD AND PLUG
Barrett-Haentjens & Co., Hazleton, Pa. (plug).
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.

VALVES, RUBBER, GLASS AND LEAD LINED
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATORS
Jeffrey Mfg. Co., Columbus, Ohio.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

WASHING MACHINERY, SAND AND GRAVEL
Dorr Co., 247 Park Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

WASTE GAS BURNERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

WASTE (INDUSTRIAL) TREATMENT
Dorr Co., 247 Park Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Hellige, Inc., 3702 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.

WATER LEAK, LOCATING INSTRUMENTS
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER MAIN CLEANING
National Water Main Cleaning Co., 50 Church St., New York City.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Inertol Co., Inc., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Sika, Inc., 1943 Grand Central Terminal, New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

WATER PURIFICATION EQUIPMENT
Dorr Co., 247 Park Ave., New York City.
Everson Mfg. Co., 627 W. Lake St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER RECORDING INSTRUMENTS, MEASURING EQUIPMENT
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

WATER SEAL PUMPING UNITS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

WATER SOFTENERS
International Filter Co., 59 E. Van Buren St., Chicago (lime-soda).
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit, Inc., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.

WATER SUPPLY SYSTEMS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.

WEATHERPROOF PAINTS, ROOF COATINGS
Inertol Co., 401 Broadway, New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

WEIGHERS, AUTOMATIC BATCH
Fuller Co., Catasauqua, Pa.

WINDOW GUARDS
Stewart Iron Works, Cincinnati, Ohio.

WIRE MESH PARTITIONS
Stewart Iron Works, Cincinnati, Ohio.

ZEOLITE MINERALS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

ZEOLITE WATER SOFTENERS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS*—WHERE TO FIND IT

By L. H. ENSLOW
Editor WATER WORKS AND SEWERAGE

The subject which has been assigned me is of a rather large order and will be dealt with only in part. I will content myself with stating where information of various sorts may be found.

It goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manual published by the American Water Works Association—"Water Works Practice."

Regardless of the availability of published information, reference books, etc., it is well known that practical experience is essential in solving most water and sewage problems.

Reference Works. Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference work for water sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists. I was somewhat reticent about taking the sole responsibility of naming such a list and therefore called on men fully qualified to offer suggestions to make up a set of reference works.

I had not thought of catalogs put out by manufacturers as being of value beyond use in specifying and purchasing materials and equipment, but one of my collaborators who is Superintendent of Operations of a company operating a large number of plants states the following:

"I find that in my own work the most frequently consulted books are the catalogs of the manufacturers of water works materials and equipment. These catalogs are of constant use, not only in connection with the purchasing of the goods listed, but also due to the vast amount of information contained in them as to the available styles, weights, dimension, capacities, and many other features."

Small Works and Large Works. It had been my thought that I might make up a list of reference works which would cover the needs of managers and operators of small and medium sized works and another which would be more extensive for the larger works. A superintendent of a small works writes as follows, and I am forced to agree with him to a major degree.

"In my opinion, the small town superintendent should have just as complete knowledge of fundamentals as the large town superintendent and in fact would have problems coming to his personal attention which might require more detailed knowledge than would be the case with the superintendent of a large system who would delegate such work to various assistants."

Current Information. Current information is best obtained through the technical journals, trade papers, manufacturers' publications.

Attending meetings, listening to papers read and discussion of these, is of paramount value. Demonstrations such as those put on during meetings are extremely valuable and operations of this nature can not, as a rule, be found described in books. Operating papers in the journals and trade publications, however, frequently describe "operating kinks" of a great value.

Reprints and Bulletins. Manufacturers and Trade Associations frequently distribute information of value in the nature of reprinted articles, house-organs or bulletins. Ofttimes these are mailed out only upon request, or by sending in a coupon incorporated in an advertisement. It therefore pays to read the ads.

Such publications usually contain valuable information and often serve a very useful purpose. If they are not bulky these may be filed away or placed in a loose leaf binder under the heading of the subject matter, as for example, "Meters and Meter Maintenance," "Tanks and Standpipes," "Water Treatment," "Algae Control," etc., etc. If bulky, they may be torn apart and the most valuable parts filed for future reference. It is surprising how much worthwhile information and data can thus be accumulated in a readily available form and at practically no cost. Some men make a practice of tearing apart technical magazines and filing the desired contents under subject matter heading where the information will be more readily available thereafter.

Filing Schemes. I have found the following filing schemes practical, serviceable and inexpensive:

For the office, the old fashioned and inexpensive box letter-file, made of cardboard and wood, is very useful. The index is removed and the clippings, reprints, etc., covering a single "subject-head" are placed in envelopes or folders properly labeled and preserved in the box files. These boxes are properly labeled to show their subject matter contents and stored on end on a shelf as one would store a set of books. As the contents of a single box grows it may be necessary later to devote an entire box to a single subject head. "Water Treatment" for example will probably require a single box which may contain a folder on water softening, and others on coagulation, aeration, corrosion control, etc. One subject head can be broken down into as many sub-divisions as may appear desirable. I have one which contains 16 sub-divisions and this assists in prompt location of the desired information when needed.

Some people may prefer to use metal box files of the same size which are also available, but more expensive. Others may prefer a set of loose leaf binders, but I find the boxes are simpler, offer more protection to the filed sheets and keep the dust out.

Information such as conversion factors, data tables and formulae which are more frequently used may best be filed in a pocket-size loose leaf book. The paper can be reinforced with little gummed linen eyelets where the rings pass through and the sheet folded if need be to fit into the binder or it may be cut into parts and glued at its corners to both sides of a filler sheet of the binder. An index in the binder serves a useful purpose in that it facilitates location of the desired tables of data or conversion figures. For work in the field the pocket size loose-leaf book is almost indispensable. I have one fairly well filled with curves and data cut from magazines, journals, and booklets distributed by manufacturers.

Short Courses for Superintendents and Operators. This scheme has been followed successfully in many states. The courses are so arranged that those taking it are not in the least embarrassed by any lack of prior education. Much of the course is of a practical nature and the chemistry and biology lectures and laboratory work are made simple and attractive. Superintendents who have attended these schools have found them very helpful and have returned to take the courses another year, which is an excellent indication of their usefulness. Materials men, factory representatives, sales engineers and other specialists are called upon to give demonstrations of important equipment used in water works systems. All of this is very useful and helpful to the manufacturer as well as the "students." Questions are freely asked and answered.

I do not hesitate to recommend the Short Course to every one of you and I believe that you will find the slight expense and the time spent a thoroughly good investment.

Special and Unusual Problems. When a special or an unusual problem presents itself to water works or sewage works operators, information required may not be easily found in published form. In such instances the State Health Department personnel can be of material help and I can assure you, as a former operator and later affiliated with two State Departments of Health, that the engineers and chemists connected with the Department are always glad to assist the operator or the management of a public works wherever they can. Call freely on your Health Department Engineer for information and advice and you will be the gainer.

In instances, the problem will be of a nature that can be solved by utilizing information obtainable through the Research

*A paper presented before the Southeastern Section, American Water Works Association. Revised in 1936.

and Development Departments of manufacturers, Institutes, or Trade Associations. In my capacity of Research Engineer of the Chlorine Institute I have frequently been able to supply special information covering problems in chlorine application which, of nature, I was better prepared to give than someone else because of my long and intimate contact with chlorinating problems. Other associations are equipped to give similar service in connection with their products.

I have not understood why consulting engineers and chemists are not more regularly approached for advice and information covering special problems. I believe that managers of water and sewage systems overlook the value of having their municipality retain consultants on an annual fee basis in order to be in a position to seek advice as frequently as need be by mail or 'phone. This is practiced by some cities but as a rule the small municipalities, which would profit relatively more perhaps than the larger cities by such an arrangement, fail to take advantage of this relatively low cost service. Consultants are not prone to charge small municipalities as heavy as they would those more able to pay. Industry finds that it pays to retain consultants on an annual fee basis and it sems that municipalities should find the same.

I believe that every home should have its family physician and that every municipality needs the services of a consulting engineer to prescribe "remedies" over the 'phone just as the family physician does and thus frequently saves the patient much discomfort or prevents the necessity of a "major operation" later.

I find an increasing tendency on the part of small towns to retain chemists and engineers to supervise plant operations and at the same time supply advice and information whenever required. If engineers and chemists were as good salesmen as are lawyers and physicians, more of this kind of valuable service would be made use of.

Visiting. An excellent means of procuring information covering operation and maintenance is by visiting water and sewage works plants. Many of us are prone to inspect the works of our neighbors with a critical eye. We see too easily the weak points. If, on the other hand, we should look around and make inquiries in a less critical frame of mind, or with an attitude of seeking all possible information, more of value could be learned.

When one attends a water or sewage works meeting or a short course he is actually "visiting" because there he meets and tasks with men from other places. That is next in value to an actual visit or first hand inspection of the other fellow's works. I wish to stress the importance of visiting and exchanging experiences.

Acknowledgment. I acknowledge, with appreciation, the assistance of the several men who contributed suggestions of reference books, catalogs, etc., which proved helpful in preparing the following lists:

LIST NO. 1—FOR THE SMALLER WATER WORKS MANAGERS AND OPERATORS

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A.	Williams & Wilkins, Baltimore	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Supply Control (F)	N. Y. State Dept. Health, Albany, N. Y.	
Water Works Handbook	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control	Williams & Wilkins, Baltimore, Md.	Hopkins
Standard Methods of Water Analysis	A. P. H. A., New York City	
Water Purification	McGraw-Hill Co., New York City	Ellms
Manual of the American Steel & Wire Co. Water Purification (F)	Amer. Steel & Wire Co., Chicago, Ill.	Brown
Use of Copper Sulphate in Control of Microscopic Organisms (F)	Nichols Copper Co., New York City	Hale
*Chlorination of Water	John Wiley & Sons, New York City	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Reprints of Articles on Chlorine and Its Application	The Chlorine Institute, New York City	Various
Hydraulic Tables	John Wiley & Sons, New York City	Williams & Hazen
Cameron Hydraulic Data (F)	Ingersoll-Rand, Phillipsburg, N. J.	
Handbook on Fire Protection	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables	National Board of Fire Underwriters, N. Y. C.	
Plumber's Handbook	McGraw-Hill Co., New York City	Dibble
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago, Ill.	
Examination of Water	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Lime—Its Use in Water and Sewage Treatment (F)	National Lime Assn., Washington, D. C.	
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C.	Hoover
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md.	
Water Supply Enginering	McGraw-Hill Co., New York City	Babbitt & Dorland
Microscopy of Drinking Water	John Wiley & Sons, New York City	Whipple
Plane Surveying	John Wiley & Sons, New York City	Tracey
Water Works & Sewerage Reference & Data Book	Gillette Publishing Company, Chicago, Ill.	

Journals and Magazines

Journal American Water Works Association
Journal New England Water Works Association
Technical Magazines—one or more.

Footnote: *Needs revision badly, but is best book of its kind now available.
(F) Available as Free Publications.

LIST NO. 2—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1 for smaller works)

Books	*Publishers*	*Authors*
Fresh Water Biology	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae	McGraw-Hill Co., New York City	Smith
Elements of Water Bacteriology	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies"	Ohio Geological Survey, Columbus, O.	C. W. Foulk
The Determinations of H. Ions	John Wiley & Sons, New York City	Whipple, Fair & Whipple

pH and Its Practical Application	Williams & Wilkins Co., Baltimore, Md	LaMotte, Kenny & Reed
Microscopy of Drinking Water	John Wiley & Sons, New York City	Whipple, Fair & Whipple
Elimination of Tastes and Odors in Water	Mc-Graw-Hill Co., New York City	Baylis
Boiler Feedwater Purification	Mc-Graw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment	Chemical Catalog Company, New York City	Buswell
Water Borne Typhoid Fever Outbreaks	Williams & Wilkins Co., Baltimore, Md	Wolman & Gorman
Textbook of Bacteriology	Appleton & Co., New York City	Hiss & Zinsser
Corrosion; Causes and Prevention	McGraw-Hill Co., New York City	Speller
Water Supply Paper 274	U. S. Geological Survey, Washington, D. C.	Stabler
Studies of Efficiency of Water Filtration Processes	U. S. Public Health Ass'n., New York City	
Water Supply Engineering	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (F)	Carnegie Steel Corp., New York City	
Handbook on Pumps (F)	Worthington Pump Co., Harrison, N. J	
Business Law for Engineers	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook	John Wiley & Sons, New York City	Kent
Elements of Hydraulics	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation	McGraw-Hill Company, New York City	Maltbie
Public Utility Rates	McGraw-Hill Co., New York City	Barker

(F) Available as Free Publications.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants (F)	New York State Dept. Health	N. Y. State Dept. Health
Arithmetic of Sewage Disposal	John Wiley & Sons, New York City	Imhoff & Fair
Sewerage and Sewage Disposal (A Text Book)	McGraw-Hill Co., New York City	Metcalf & Eddy
Chemical Analysis of Water and Sewage (with explanatory sections)	Edwards Brothers, Ann Arbor, Mich	Eldridge & Theroux
Sewerage and Sewage Treatment	John Wiley & Sons, New York City	Babbitt
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Sewerage	John Wiley & Sons, New York City	Folwell
Manual of Sewage Works Operation	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst. N. Y. C.	
Sewage Chlorination (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Sewage Disposal	John Wiley & Sons, New York City	Kinnicutt, Winslow & Pratt
Lime—Its Use in Water and Sewage Treatment (F)	National Lime Assn., Washington, D. C.	
Chemical Treatment of Sewage (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Water Works and Sewerage Reference & Data Book	Gillette Publishing Co., Chicago, Ill.	

JOURNALS AND MAGAZINES

Sewage Works Journal.....
Technical Magazines—one or more.....
(F) Available as Free Publications.

LIST NO. 4—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS

(In addition to List No. 3 for smaller works)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment	John Wiley & Sons, New York City	Babbitt
Sewage Disposal	McGraw-Hill Co., New York City	Fuller
The Chemistry of Water and Sewage Treatment	Chemical Catalog Co., New York	Buswell
The Hoover Plumbing Code (F)	U. S. Bureau of Standards	
Public Health Reports Bulletin No. 132	U. S. Public Health Service	

(F) Available as Free Publications.

WATER

A Discussion of Flows, Friction, Measurement and Power*

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream.

Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

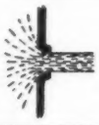
As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12
Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	**ORIFICE WITH WELL-ROUNDED ENTRY** There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from Technical Bulletin No. 21, recently issued by National Tube Co. of Pittsburgh, Pa.—Ed.

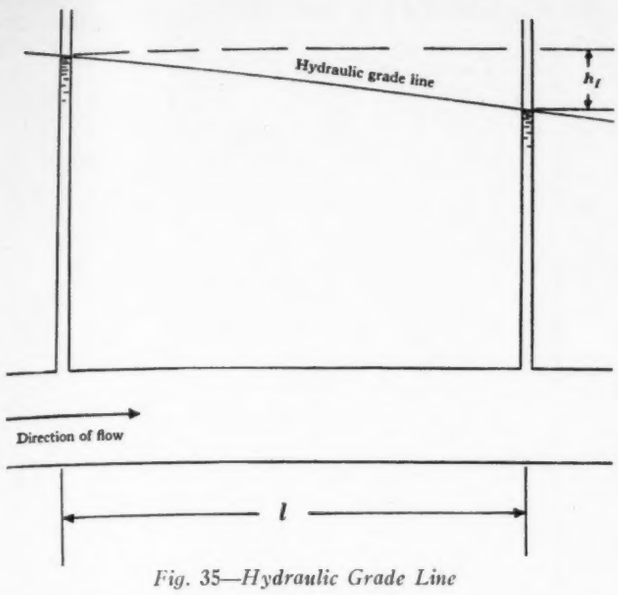


Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	3	4,320	1.114	6.72	8.94	12.5	18.9
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.86	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551.	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.892	1.19	1.66	2.51
		8	11,520	.765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1.147	3.22	4.28	6.00	9.07
		16	23,040	1.530	5.48	7.30	10.2	15.5
		20	28,800	1.912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.19
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1.675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.61	7.58	8.79	12.3
		100	144,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0.325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.504	0.322	0.370	0.429	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.35	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.441	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7.63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27.5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47.7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3.85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{0.526} D^{0.58}}{K_s{}^{0.526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe*
Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hf) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.89
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
6	5.440	800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2.321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed longitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.035t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.035t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

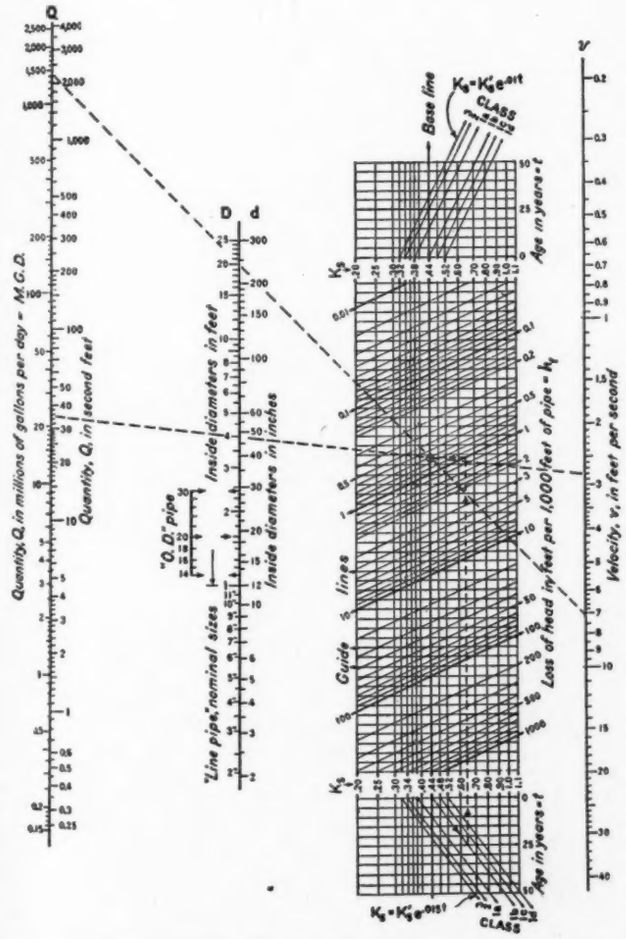

Q
v
D d
Quantity, Q, in millions of gallons per day = M.G.D.
Quantity, Q, in second feet
Inside diameters in feet
Inside diameters in inches
"Line pipe," nominal sizes
"Q.D." pipe
Base line
Guide lines
Loss of head in feet per 1,000 feet of pipe = h_f
Velocity, v, in feet per second
Age in years = t
CLASS
$K_s = K'_s e^{0.01t}$
$K_s = K'_s e^{0.035t}$

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to 0.06$\times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence $= \pm 5$ degrees	$\frac{1}{7}$ to $\frac{1}{10}$ Where v is the throat velocity
For total angle of divergence $= \pm 15$ degrees	$\frac{1}{3}$ to $\frac{1}{6}$
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅓ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head $= \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head $= \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head $= \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40\, v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\, v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\, v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

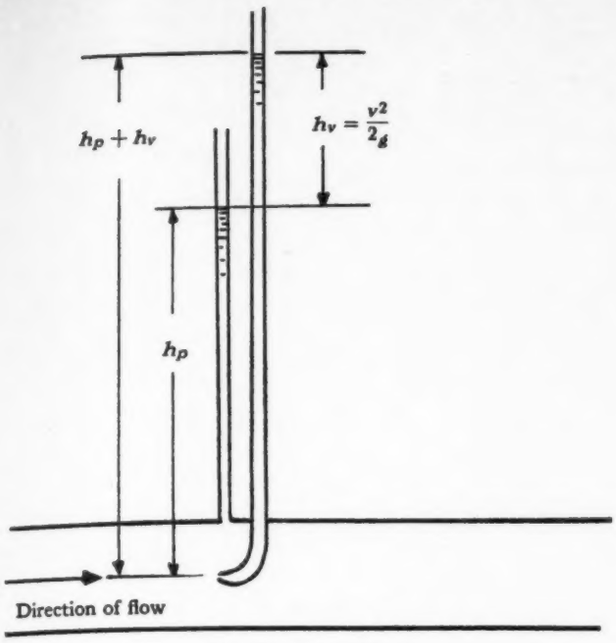


Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_3.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
Cv = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

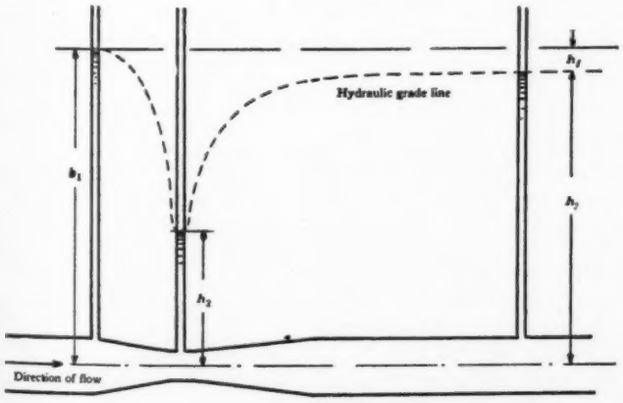


Fig. 38—Venturi Meter

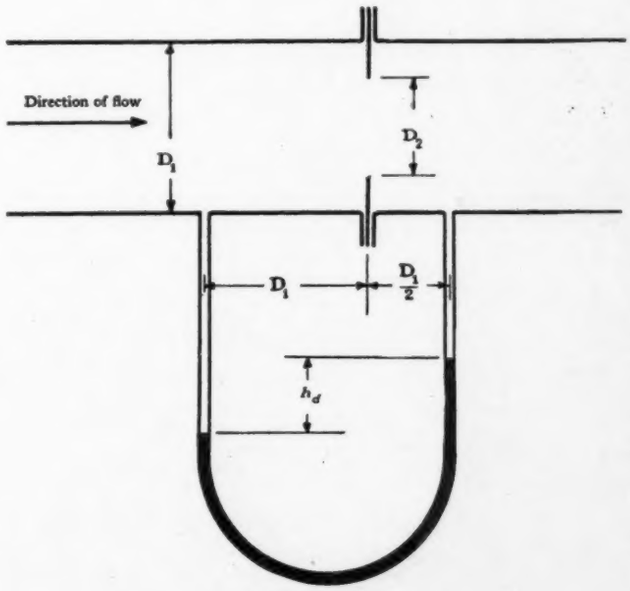


Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{D_2}{D_1}\right)}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

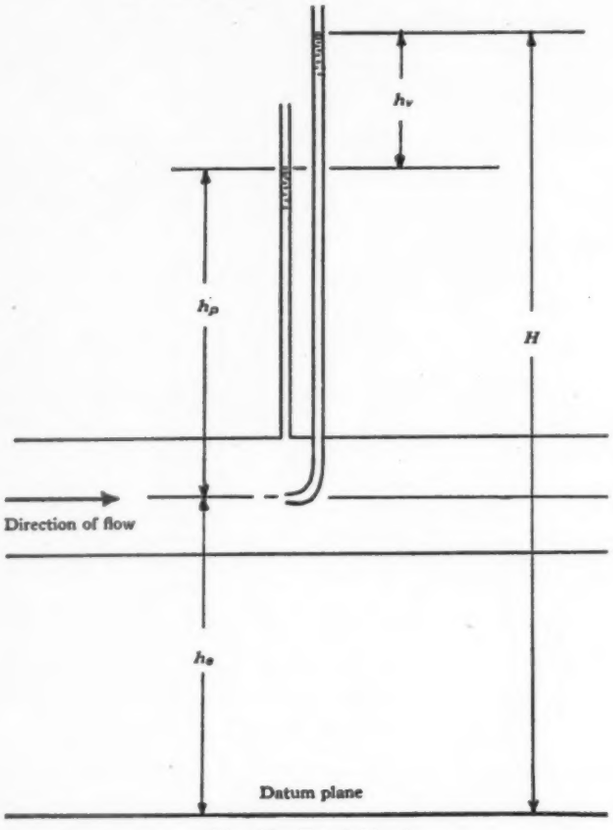


Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029405
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.
P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_2}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

PRACTICAL HYDRAULICS*

By P. S. WILSON

Consulting Engineer, Glen Ridge, N. J.

I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.

L = Length of the weir crest in feet.

h = Head on the weir in feet.

$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3}/^{2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

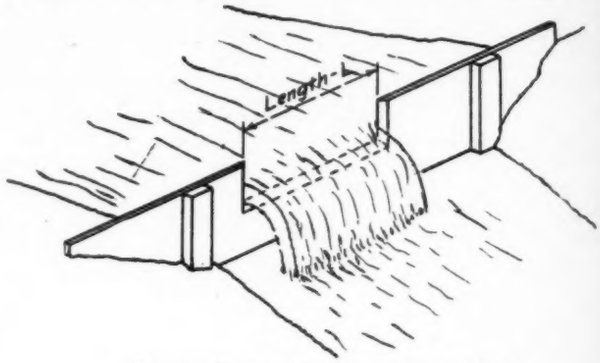


Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

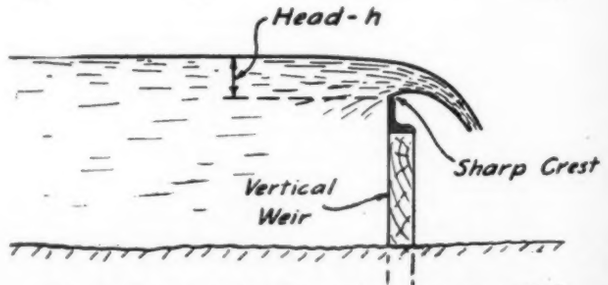


Fig. 2—Cross Section Rectangular Sharp Crest Weir

*From WATER WORKS AND SEWERAGE, April and June, 1934.

II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions*. In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length (3.0 — O.z) = 2.8 feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which would be a negligible error except in the most precise measurements.

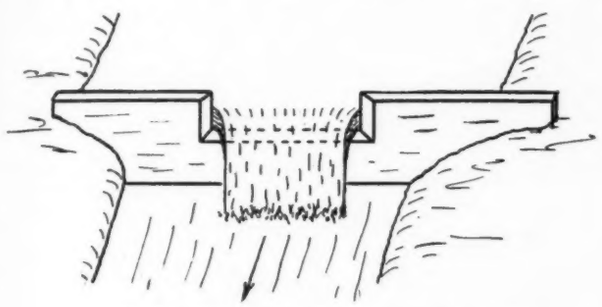


Fig. 3—Weir with End Contractions

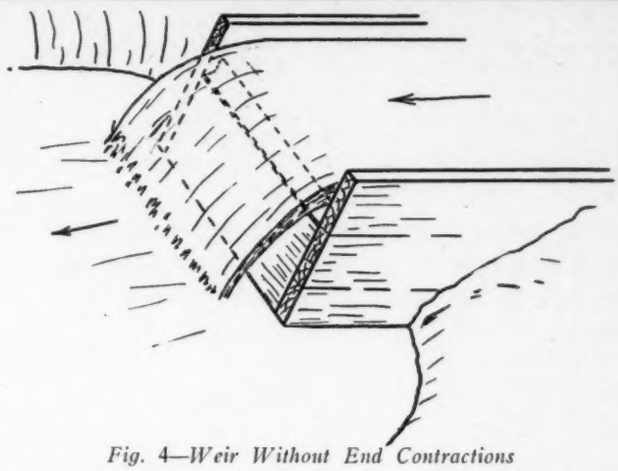


Fig. 4—Weir Without End Contractions

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER*

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes

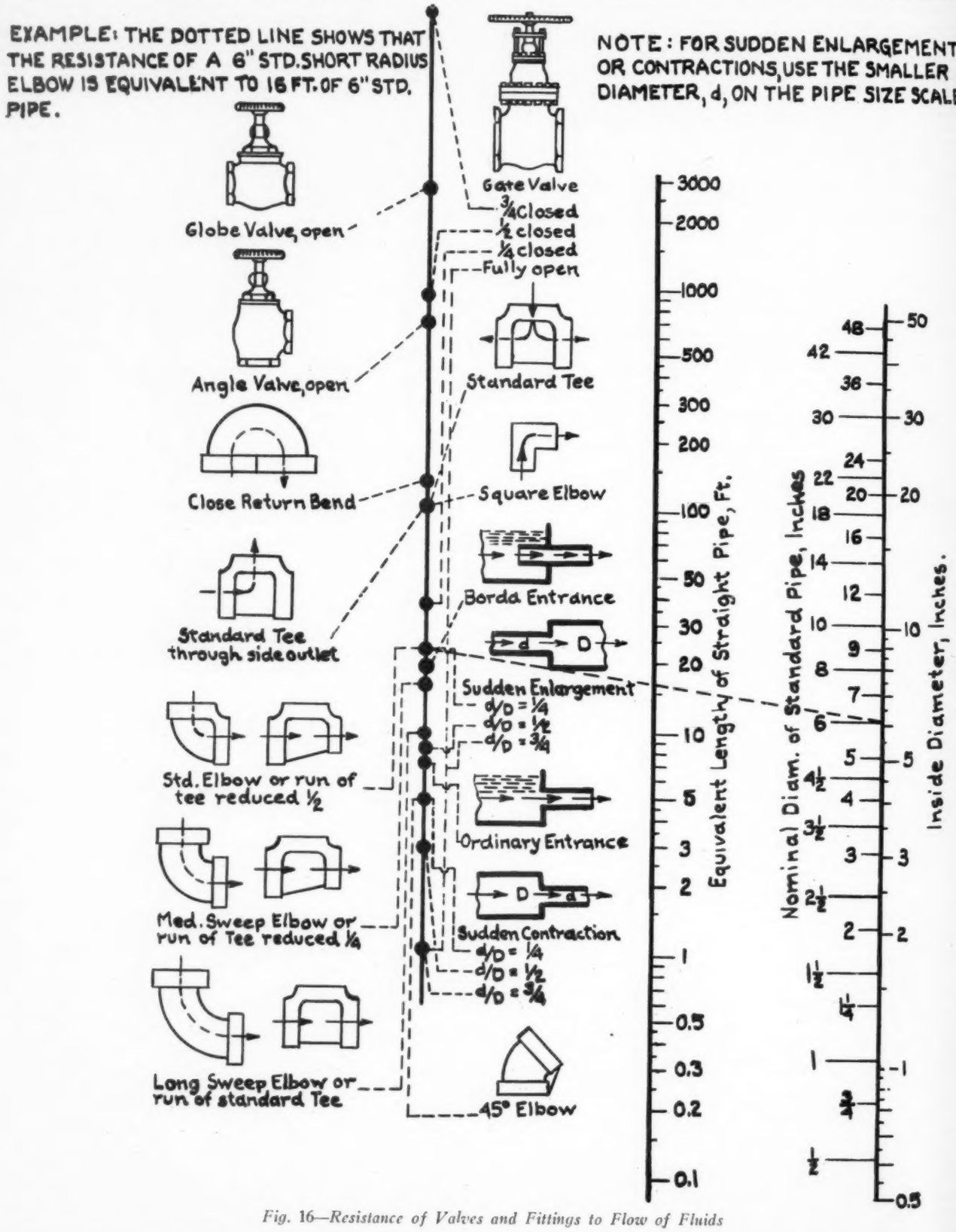


Fig. 16—Resistance of Valves and Fittings to Flow of Fluids

TABLE I—FLOW OF WATER THROUGH STD. W.I. OR STEEL PIPES IN FAIR CONDITION

Note.—For old rough pipes add 25 per cent to pressure drop given in the table. Figures in bold face type are for the usually allowed range of velocities, 2.0 to 10.0 ft. per second. Figures market this * are for 5.0 ft. per sec. velocity (approx.).

Discharge Gallons Per Min.	PRESSURE DROP, POUNDS PER SQ. IN. PER 1000 FT. OF PIPE (1.0 Lb. per Sq. In.=2.30 Ft. of Water)									
	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	4½"	5"
1	.55									
2	**2.0**	.50								
3	**4.25**	1.08	.50							
4	**7.3**	1.85	.86							
5	**11.1**	2.81	1.31							
6	**15.4**	3.94	1.82	.52						
8	**25.3**	6.70	3.11	.88						
10	**40.0**	10.2	4.70	1.34	.55					
15	**85.0***	21.8	10.1	2.85	1.18					
20	**145**	36.8*	17.1	4.85	2.00	.68				
25		56.0	26.0	7.32	3.04	1.02	.49			
30		78.5	36.4*	10.4	4.26	1.44	.69			
35		100	48.3	13.7	5.14	1.92	.93	.49		
40			62.5	17.6	7.29	2.45	1.18	.63		
45			78.0	22.1	9.12	3.08	1.49	.79	.45	
50			94.0	26.7*	11.0	3.72	1.80	.96	.54	
60				37.5	15.5	5.20	2.54	1.24	.77	
70				51.8	21.4	7.25	3.48	1.86	1.06	.57
80	6"			63.8	26.4*	8.90	4.33	2.30	1.32	.70
90				79.1	32.8	11.1	5.31	2.86	1.63	.87
100	.45			96.8	40.0	13.5	7.78	3.47	2.37	1.06
125	.68				60.6	20.5*	9.90	5.28	3.02	1.62
150	.95				65.2	28.8	13.9*	7.40	4.24	2.28
175	1.26	8"			86.6	39.0	18.4	9.80	5.60	3.00
200	1.62					49.0	23.6	12.6*	7.40	3.85
225	2.00	.51				60.6	29.3	15.6	8.90	4.76
250	2.45	.63				74.1	35.8	19.0	10 9*	5.85
275	2.93	.74				88.2	42.6	22.8	13.0	6.92
300	3.44	.87				104	50.2	26.8	15.3	8.20*
325	3.98	1.02					58.0	31.0	17.8	9.55
350	4.55	1.12	10"				66.8	35.7	20.3	10.9
375	5.17	1.32					75.2	40.3	23.0	12.4
400	5.85	1.49	.48				85.3	45.5	26.2	14.0
425	6.53	1.67	.53				95.3	50.7	29.1	15.6
450	7.28*	1.85	.59				108	56.8	32.8	17.4
475	8.07	2.05	.66				118	62.8	35.8	19.2
500	8.90	2.28	.73					69.3	39.6	21.3
550	10.6	2.71	.87	12"				82.7	47.3	25.4
600	12.5	3.18	1.02					97.0	55.4	29.8
650	14.4	3.67	1.18	.48				112	64.0	34.5
700	16.6	4.23	1.36	.55					74.0	39.7
750	19.0	4.80	1.54	.63	14"				84.0	45.0
800	21.3	5.41*	1.73	.70					94.5	50.8
850	23.7	6.05	1.94	.79	.48				106	56.7
900	26.4	6.72	2.16	.87	.53					62.8
950	69.2	7.45	2.38	.96	.59					69.6
1,000	32.3	8.18	2.63	1.06	.65	16"				76.8
1,100	38.6	9.82	3.15	1.27	.78					91.8
1,200	45.1	11.6	3.64*	1.50	.91	.45				108
1,300	52.5	13.4	4.30	1.74	1.06	.52				
1,400	60.0	15.4	4.88	1.99	1.22	.60				
1,500	68.8	17.5	5.59	2.28	1.39	.69	18"			
1,600	77.1	19.7	6.29	2.56	1.56	.77				
1,800	96.1	24.5	7.85	3.19*	1.93	.96	.52			
2,000	117	29.9	9.57	3.86	2.37*	1.17*	.63	20"		
2,500		45.1	14.5	5.88	3.58	1.77	.96			
3,000		63.2	20.4	8.23	5.02	2.49*	1.35	.55	24"	
3,500		84.0	27.2	10.9	6.68	3.31	1.79*	.78		
4,000		108	34.7	14.1	8.52	4.22	2.29	1.04	.51	
4,500			43.2	17.4	10.6	5.22	2.85	1.32*	.64	
5,000			52.3	21.3	12.9	6.40	3.48	1.64	.79	
6,000			73.1	29.8	18.2	8.96	4.85	2.00	1.09	
7,000			98.0	39.6	23.2	11.9	6.47	3.74	1.45*	
8,000			125	50.9	30.9	15.2	8.25	4.76	1.86	
9,000				62.8	38.3	19.0	10.3	5.90	2.20	
10,000				77.0	46.7	23.4	12.2	7.22	2.92	
12,000				108	66.0	32.7	17.7	10.2	3.96	
14,000					87.5	43.3	23.6	13.5	4.51	
15,000					99.4	49.5	26.7	15.3	5.99	
16,000					112	55.4	30.2	17.4	6.76	
18,000						69.2	37.6	21.6	8.45	
20,000						84.8	45.6	26.4	10.3	
22,000						100	54.0	31.2	12.2	
24,000							63.8	36.8	14.3	
25,000							69.0	39.6	15.4	
30,000							96.2	55.5	21.6	
35,000							129	74.2	28.8	
40,000								95.3	37.0	
45,000								119	45.9	
50,000									56.0	
55,000									66.8	
60,000									78.2	

a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

*From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

The equivalent length of pipe has been based upon the pressure drop values given in Table I for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

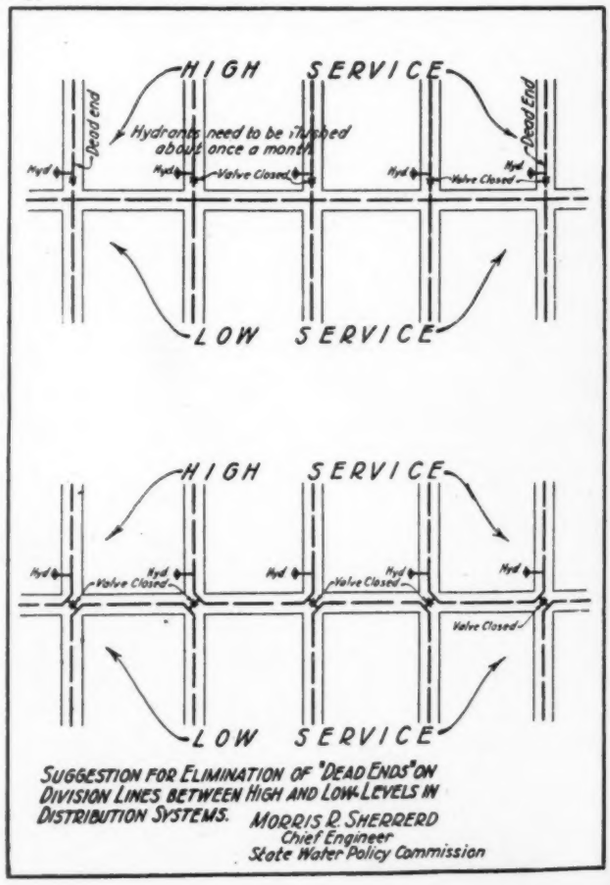
H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
$2g = 64.4$

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

One Method of Eleminating Dead Ends

A means of eliminating dead ends of water mains where there are two types of water service, has been developed by Morris R. Sherrerd, Chief Engineer, New Jersey State Water Policy Commission.

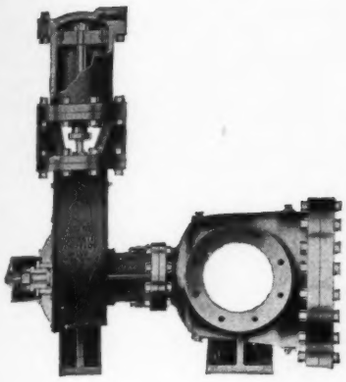
The lower part of the illustration shows how by having a short gated connection between the two services, and by running the main around the block or square without using a cross fitting, dead ends are eliminated.



SUGGESTION FOR ELIMINATION OF "DEAD ENDS" ON DIVISION LINES BETWEEN HIGH AND LOW LEVELS IN DISTRIBUTION SYSTEMS. MORRIS R. SHERRERD Chief Engineer State Water Policy Commission

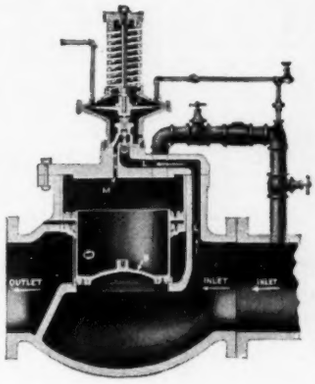
GOLDEN-ANDERSON VALVE SPECIALTY CO.

1350 Fulton Bldg.
PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.

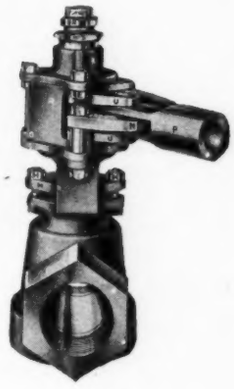


ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24″.

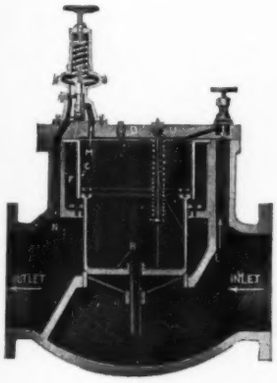
THRU-FLOW PLUG VALVE

Furnished all sizes for lever or handwheel control. Axially unseats and rotates without rub or wear. Easy to operate under hydraulic pressures. Furnished for any liquid services with round port opening.



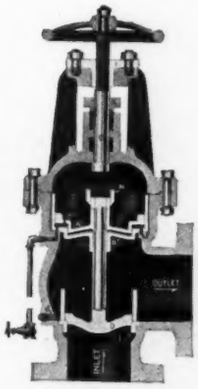
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24″.



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24″.

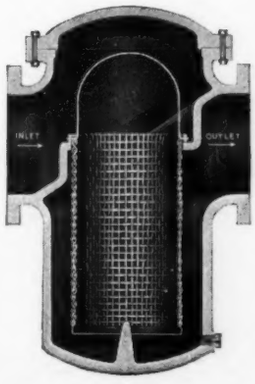


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12″ in angle, globe or elbow patterns.

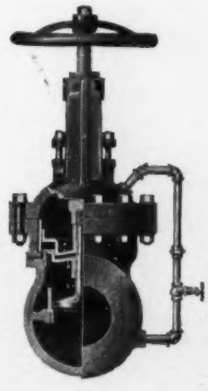
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24″.



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12″ sizes.



SIMPLEX VALVE & METER COMPANY

6749 Upland Street, Philadelphia, Pa.

SIMPLEX REPRESENTATIVES

ATLANTA, GA., W. D. Taulman, 179 Spring St., S.W.
CHARLOTTE, N. C., T. C. Heyward, Independence Building
CHICAGO, ILL., A. F. Barron, 59 East Van Buren Street
CLEVELAND, OHIO, Tomlinson-MacLachlan, Inc., 1603 St. Clair Ave.
DENVER, COLO., Mountain States Machinery Co., 1526 Blake St.
DETROIT, MICH., DuBois Company, 2832 E. Grand Blvd.
HOUSTON, TEXAS, M. N. Dannenbaum Co., 1001 Shell Bldg.
KANSAS CITY, MO., Butters Pump & Eq'p't Co., 200 Pickwick Hotel
LOS ANGELES, CALIF., Ralph W. Lawton, 137 N. Van Ness Ave.
LOUISVILLE, KY., R. M. Overstreet, 1441 So. 4th Street
MILWAUKEE, WIS., F. H. Dorner, 1107 E. Knapp Street
MINNEAPOLIS, MINN., Kent-Ervin Engr. Co., 732 Builders Exch. Bldg.
NEW ORLEANS LA., A. C. Hays, 1415 Carondelet Bldg.
NEW YORK, N. Y., W. K. Sowdon, 342 Madison Avenue
OMAHA, NEBR., O. F. Barklage & Co., Keen Hotel Bldg.
ROCHESTER, N. Y., A. L. Covill, 1041 Granite Bldg.
SALT LAKE CITY, UTAH, C. E. Painter, 149 W. Second South St.
SAN FRANCISCO, CAL., Water Works Supply Co., 501 Howard St.
SEATTLE, WASH., Palmer Supply Co., 222 Westlake Ave. North
TULSA, OKLA., McGregor Engineering Co., P. O. Box 1141
EL PASO, TEXAS, LeRoy G. Hetrick, 209 Mills Building
TORONTO, ONT., CANADA, Simplex Valve & Meter Co. of Canada, Ltd.

PRODUCTS:

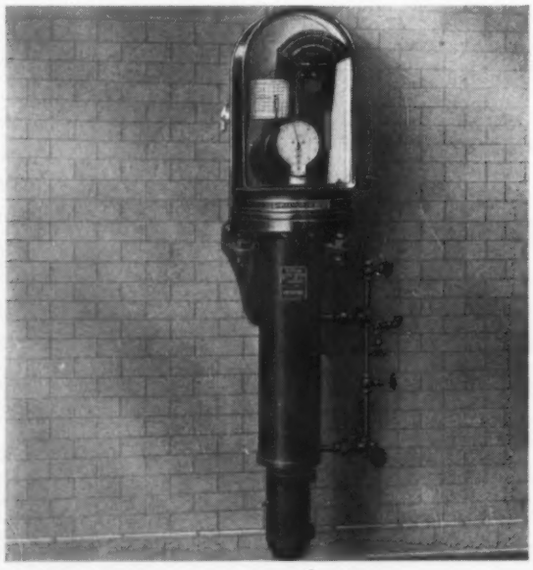
Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Pitot Tubes and Manometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Sewage Aerators; Rotary Distributors; Hydraulic Equipment of Special Design.

SIMPLEX METER REGISTERS:

Primarily designed for use with Venturi tubes, Simplex meter registers can, when necessary, be operated by pitot tubes, orifices, etc. They are adapted for use in measuring liquids and gases under all pressure conditions and are particularly adapted for the measurement of raw water; filtered water; raw sewage; screened sewage; digested sludge; air; oil; etc. Simplex meters are noted for their adaptability to operate under small Venturi heads and to measure accurately the lowest flows corresponding to water differentials from one-eighth inch and upward.

Particularly designed to measure accurately the slightest change in rate of discharge over a wide measuring range, Simplex meters can be furnished to either indicate, record, or totalize the flow or in any combination of these functions.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity of response may be checked at any time, during its period of service.



SIMPLEX FILTER RATE OF FLOW CONTROLLERS:

Provide an efficient device for the operation of gravity or pressure filters which maintain the rate of discharge through the bed at a constant regardless of variations in pressure or

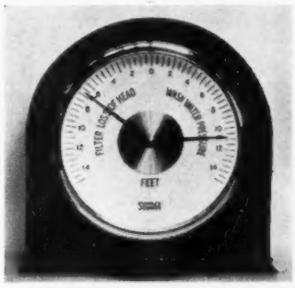
Partial Capacity List of Venturi Tubes and Simplex Meter Registers

Dia. Pipe, In.	Catalog No. for Ordering	Cold Water gallons per day	
		Maximum	Minimum
2	2x 25/32	.....	.....
	2x 29/32	.....	.....
	2x 1	.....	.....
	2x 1⅛	.....	.....
3	3x 1	.....	.....
	3x 1¼	.....	.....
	3x 1½	.....	.....
4	4x 1 17/32	.....	.....
	4x 1¾	.....	.....
	4x 2	356,000	18,000
5	5x 1¾	265,000	13,300
	5x 2	348,000	17,500
	5x 2½	555,000	28,800
6	6x 2½	547,000	27,400
	6x 2¾	665,000	33,500
	6x 3	800,000	40,000
8	8x 3	780,000	39,000
	8x 3⅜	1,000,000	50,000
	8x 4	1,420,000	71,000
10	10x 4	1,400,000	70,000
	10x 5	2,220,000	111,000
	10x 6	3,320,000	166,000
12	12x 5	2,220,000	110,000
	12x 6	3,320,000	160,000
	12x 7	4,480,000	224,000
14	14x 6	3,170,000	160,000
	14x 7	4,360,000	220,000
16	16x 7	4,300,000	216,000
	16x 8	5,680,000	285,000
	16x 9½	8,300,000	415,000
18	18x 9	7,200,000	360,000
	18x10	9,000,000	450,000
20	20x10	8,900,000	445,000
	20x12	13,300,000	666,000
	20x13	16,000,000	800,000

water level, utilizing as an operating means only the pressure effect of the water flowing through the filter effluent line.

Simplex controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; and are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any electrical mechanisms in their operation; start quickly from a wide open position and take the rate for which set in less than fifteen seconds.

The Simplex, direct-acting controller is arranged for either straight-through, right, or left-hand outlet as may be desired.



SIMPLEX FILTER GAUGES:

These may be had in many combinations of Indicating Recording and Totalizing, both the Rate of Flow and the Loss of Head.

They are mercury float operated, the Simplex Bell Shaped Float is utilized in the Rate Gauge which provides uniform graduations of flow on both the Indicating Dial and Recording Chart.

Also available for measuring depth of water in clear wells, sedimentation basis, etc., A-C Simplex water float operated gauges which may be furnished in both Indicating and Recording or combined types.

Simplex gauges are dependable, accurate and easily installed—a high grade quality product made with precision and care.

SIMPLEX AIR RELEASE AND AIR AND VACUUM VALVES:

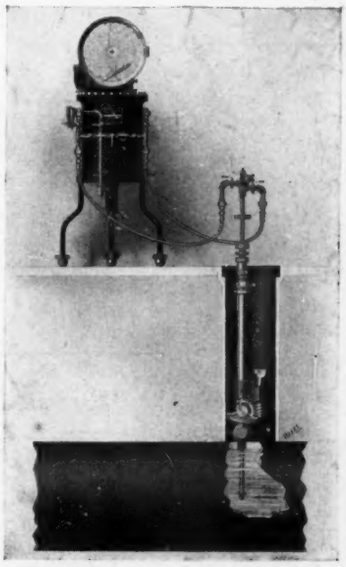
In the design and operation of large steel pipe lines flowing under gravity, consideration should be given to the possibility of collapse in case, for any reason, the internal pressure is reduced below that of atmosphere. A number of serious failures have been caused by the neglect to provide adequate means to prevent this possibility.

Simplex Air and Vacuum Valves are used on large mains where there is danger of collapse due to vacuum, the valve breaking the vacuum preventing collapse. They facilitate the filling of the main, since wide open until full of water. They are made in the following sizes: 2½", 4", 6", 8", and 10". The 2½" size is furnished with a screw thread base for nipple connection to the main pipe line. The 4" to 10" sizes are designed for a flange connection as illustrated. This may be either low pressure or heavy pressure A. S. M. E. drilling. Usual practice requires the attaching to the air and vacuum valve of a Simplex air release valve so as to vent any small accumulation of air which may be entrapped in the pipe line.

Simplex Automatic Air Release Valves have been designed to release Automatically accumulations of air. They possess the merits of continuous operation without attention; simplicity; compactness; accessibility; and low cost; all of which are proved by over fifteen years satisfaction to many users. Located on the high portions of the line, they insure automatic venting of the line and a continuous flow.

SIMPLEX PITOT TUBE RECORDERS:

For use with Simplex Round or Flat Pitot Rods—afford not only a record of velocity but can be furnished with pressure elements to give simultaneous readings of velocity and pressure.



This equipment may also be used for Water Waste Surveys or for conducting water flow investigations.

Indispensable to water works engineers for determining character of the flow in the mains of the distribution system.

SIMPLEX SEWAGE EQUIPMENT:

The Simplex Valve & Meter Company is the Eastern distributor for the Simplex Ejector & Aerator Corporation, Chicago, manufacturers of a complete line of sewage treatment equipment, including screens; clarifiers; mechanical surface aerators, for activated sludge plants; revolving sewage distributors; ejectors; and, as well, the newly-developed Simplex Aero-Filter. Competent engineers are at your service to assist you in your problems.

R·D·WOOD CO.

ESTABLISHED IN 1803

400 CHESTNUT STREET
PHILADELPHIA

WORKS, FLORENCE, N. J.

SAND-SPUN PIPE

Centrifugally Cast in Sand Molds for High Strength

"Sand-Spun" pipe is fundamentally different from pit-cast pipe in its manufacture and in its properties. It is cast in heated, spinning sand-lined molds. This process eliminates chilled iron, hardness, and brittleness, and produces a pipe with few impurities, great elasticity, and high tensile strength. The metal is close grained and ductile, making drilling and machining easy.

"Sand-Spun" pipe conforms to American Water Works Association and American Gas Association standards for Bells and Beads. It is available in unlimited quantities in sizes up to 30″, in bell and spigot, plain ends, raised ends, grooved ends, and with mechanical joints.

FITTINGS

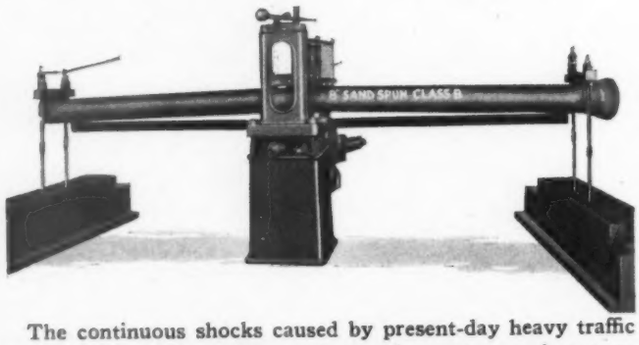
Bell and Spigot or flanged fittings made to American Water Works Association specifications.

Special castings, flexible-joint pipe, and large loam castings.

Cast iron culvert pipe.

Highly Recommended for

WATER, GAS, LIQUIDS, SEWERS



The continuous shocks caused by present-day heavy traffic on hard surfaced streets require a pipe more resistant to shock. Thus we show here an illustration of the elasticity or bending quality of SAND-SPUN pipe. This 16-foot section bent more than 3 inches without damage.

Reduced Fittings: Condensed design of bells and spigots, interchangeable with A. W. W. A. standard, A. G. A. standard, and N. E. W. W. A. standard. They effect savings in weight, space, freight, and handling.

GATE VALVES

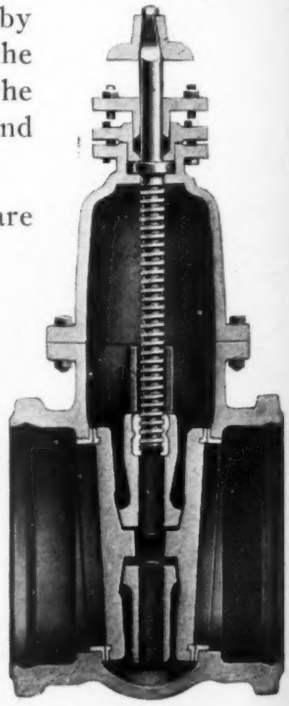
Every element in the design and construction of "Wood" Gate Valves is based on the fact that **reliability** is their all-important quality. Interruptions in service are fire hazards, or perils to health, or both.

"Wood" Valves, therefore, are primarily simple in design, rugged in construction, fully bronze mounted, and tested to twice their working pressures of 175 pounds. They fully meet specifications of American Water Works Association, with these two added features:

1. There are no pockets to fill with sediment or scale to make the valve jam.

2. The tapered seats, with double discs to assure tightness, are never rubbed or scraped by the discs, because the mechanism drops into place before it is spread by outward pressure from the center. This protects the seats against wear and abrasive action.

Wood gate valves are available in every size.



In closing, the gates lower out of the bonnet across the flow of water before the spreading action begins. The center or "hub" of the spreader then presses outwards against the discs on each side of the trunnions, creating a uniform pressure and a perfect adjustment against the seats. In opening, the spreader moves away from the discs, letting them fall free before lifting.

MATHEWS FIRE HYDRANTS

The Mathews Hydrant has been a leader for more than 60 years. Over 350,000 are in use. They have never changed in basic design, and the newest Mathews is interchangeable with the oldest.

Yet the Mathews Modernized Hydrant is the one hydrant best fitted to meet today's requirements. Not only is it simple in design, thoroughly protected against rust, and unusually strong in all its parts, but the protection-case construction offers three distinct advantages:

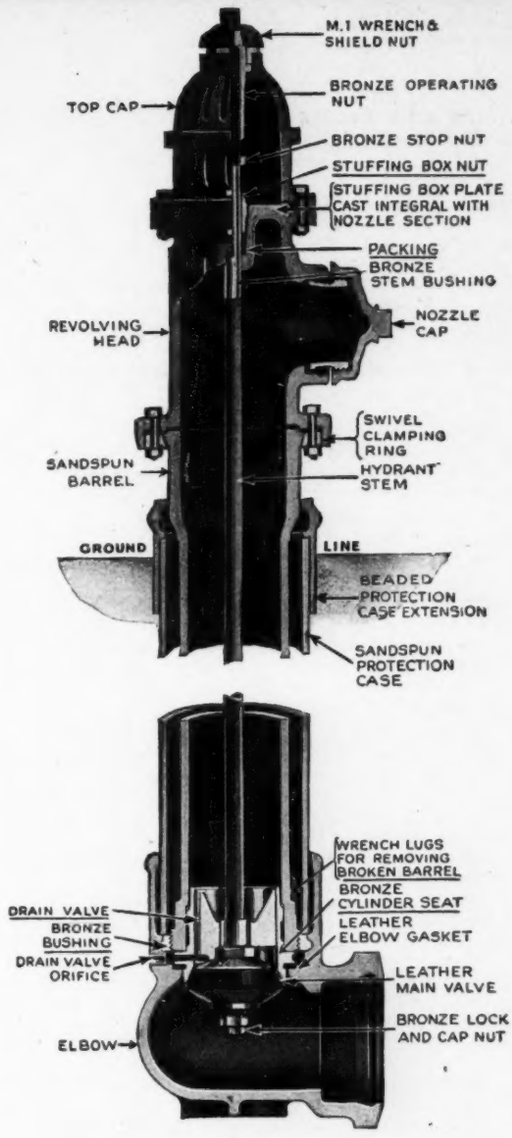
1. It prevents frost-swollen ground from heaving the hydrant, loosening it from the main, breaking it away from the main, or cracking the hydrant itself. It is only natural that tightly packed soil lifts under the action of frost, and may hoist the hydrant several inches out of position. But in the case of Mathews Hydrants, this upward pressure is exerted only on the sliding protection case. Frost cannot heave the hydrant itself and leaves it without strain at the level it was set.

2. It makes the hydrant far stronger. Not only is the full barrel-strength increased by the shock-resistance of the sand-spun protection case, but the hydrant is not weakened by any theoretical breaking point.

3. The protection case allows all working parts to be unscrewed and lifted out as a unit, whether broken by traffic, in need of overhaul, or for replacement by the modernized type. It is never necessary to dig up a Mathews Hydrant, for even grade-changes can be met by replacing the barrel with one of the proper length.

The Modernized Mathews also has the advantage of the new Swivel Flange which permits facing the nozzles in any direction, and the Shield Operating Nut which prevents rain and sleet from seeping in and freezing around the operating nut.

And remember: Traffic-broken Mathews Hydrants can be replaced without digging or breaking pavement. This is a real economy to any municipality.



MATHEWS MODERNIZED HYDRANT

Products by R. D. Wood Co.

Mathews Fire Hydrants
Gate Valves
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Drips and Syphons
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Gay Iron Castings
Hydraulic Machinery
Hydraulic Operating Valves
Automatic Gas Producers
Blast Furnace Gas Washers

PUMPS

Definitions and Values

(Adopted by the Hydraulic Society)

Efficiency, Hydraulic (Symbol e_h).—The ratio of the useful power delivered in the water at the point of discharge where measured to the power delivered to the water by the impeller at the point of exit from the impeller.

Efficiency, Mechanical (Symbol e_m).—The ratio of the water horsepower to the horsepower required to drive the pump.

Efficiency, Overall (Symbol e).—Comprises all the losses in the pump and the driver, and indicates the economy of the entire unit.

Head, Total Dynamic (Symbol T.D.H.).—Total dynamic head is the vertical distance between the source of supply and point of discharge when pumping required capacity, plus friction entrance and exit losses.

Total dynamic head, as determined on test, where suction lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance betwen point of attachment of mercury column and center of gauge, plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total dynamic head, as determined on test, where suction head exists, is the reading of a gauge attached to the discharge nozzle of pump. minus the reading gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge) plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head is the total dynamic head minus dynamic suction lift, or plus dynamic suction head.

Head, Static (Symbol H_s).—Static head is the vertical distance between the free level of the source of supply and to the point of free discharge, or to the level of the free surface of the discharge water.

Head, Velocity (Symbol H_v).—The velocity head (sometimes called "Head due to Velocity") of water moving with a given velocity is the equivalent head through which it would have to fall to acquire the same velocity; or, in other words, the head necessary merely to accelerate the water. Knowing the velocity, we can readily figure the velocity head from the simple formula:

$$h = \frac{V^2}{2g}$$

in which "g" is acceleration due to gravity, or 32.16 feet per second; or, knowing the head, we can transpose the formula to $V = \sqrt{2gh}$, and thus obtain the velocity.

The velocity head is a factor both in figuring the total head from construction data and testing.

When estimating the total dynamic head of an installation, the head equivalent to the velocity of the water leaving the end of the discharge pipe line must be added to the static and friction head.

When testing a pump, certain velocity head corrections must be made, depending on the average velocity at the point where pressure readings are taken. The customary method of testing is to use a mercury column for obtaining the suction lift and a gauge to indicate the discharge or suction head, with gauge connections at or close to the pump openings.

The mercury column at the suction will show the dynamic suction head at the point of gauge connection. Included in this dynamic suction head is the velocity head as represented by the average velocity at that point.

The discharge gauge will show the dynamic pressure head at the point of gauge connection.

The sum of the two gauge readings, corrected to the same elevation, will give the total dynamic head produced by the pump, provided water flows at the same average velocity at the point of attachment of suction gauge as of discharge gauge. This condition will exist when suction and discharge openings are of equal size.

If the discharge pipe is of smaller diameter than the suction pipe, which is often the case, then it will be necessary to add to the total head, as shown by the gauges, the difference in velocity head between that of the discharge and that of the suction pipe at the point where gauges are connected.

If the discharge pipe is larger than the suction pipe, the difference in velocity head must be subtracted from the total head.

Velocity ft. per second	1	2	3	4	5	6	7
Velocity head in ft.	.02	.06	.14	.25	.39	.56	.76
Velocity ft. per second	8	8.5	9	9.5	10	10.5	
Velocity head in ft.	1.0	1.12	1.25	1.4	1.55	1.7	
Velocity ft. per second	11	11.5	12	13	14	15	
Velocity head in ft.	1.87	2.05	2.24	2.62	3.05	3.5	

Horsepower, Brake (Symbol b-hp.).—The actual horsepower required at the pump shaft to drive the pump $= \frac{\text{w-hp}}{e_m}$.

Brake horsepower is not applicable to direct-acting steam pumps.

Horsepower, Indicated (Symbol i-hp.).—The horsepower developed in the steam or liquid end calculated from indicator cards.

Suction Head (sometimes called head on suction) exists when the pressure measured at the suction nozzle and corrected to the center line of the pump is above atmospheric pressure.

Suction Head Dynamic, where static suction head exists, is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus velocity head minus entrance, friction and velocity losses; but not minus internal pump losses.

Suction head dynamic, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center line of pump. Suction head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to suction will prevail.

Suction Head Static exists when the source of supply is above the center of pump and is the vertical distance from the free level of the source of supply to center of pump.

Suction Lift.—Suction lift exists when the suction measured at the pump nozzle and corrected to the center line of the pump is below atmospheric pressure.

Suction Lift Dynamic, where static suction lift exists, is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus velocity head, plus entrance, friction and velocity losses, but not including internal pump losses; where static suction head exists but where the losses exceed the static suction head the dynamic suction lift is the sum of the velocity head, entrance, friction and velocity losses, *minus* the static suction head, but not including internal pump losses.

Suction lift dynamic, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Lift Static exists when the source of supply is below the center of pump and is the vertical distance from the free level of source of supply to center of pump.

Viscosity is that property of a liquid which resists any force tending to produce flow. Viscosity is a property independent of specific gravity.

SOME NOTES ON ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS[1]

By HOMER E. BECKWITH*

In the past few years there has been a rapid change from steam to electrically driven centrifugal pumps, especially in the smaller water works plants. The many advantages of electric power are coming to be more and more realized, but unfortunately in many cases a full knowledge of the nature of centrifugal pumps does not seem to have accompanied their adoption. It is economy of the highest order, therefore, to secure the advice of a competent engineer before purchasing any centrifugal pumping equipment.

Centrifugal pumps are designed to operate under fixed conditions, and any appreciable change from design conditions will result in decreased efficiency.

Installations have been found where pumps were working against more than the design head, or against less than the design head, or with the discharge or suction partly closed to control the rate of discharge. Or pumps have been installed without knowledge that the friction head is a part of the total head against which the pump operates. All of these factors adversely affect the performance of the equipment to such an extent that the cost of efficient machinery is often wasted every few months through inefficient operation. Also, accidents can occur to equipment in operation which decreases its efficiency.

For some time the writer has felt that some simple method should be available to the average water works operator whereby he could check up on his pumps. Table 1 was worked up for personal use, but may prove to be of interest. A slide rule was used in its preparation, but it should be accurate to a fraction of 1 per cent. With this table, it is believed that the work of securing overall wire to water efficiencies will be reduced to a minimum. Table 1 shows the number of gallons pumped per kilowatt hour against a given head, assuming the motor and pumps have efficiencies of 100 per cent. A rough check can be made by dividing a month's pumpage in gallons by the kilowatt hours consumed. This gives the number of gallons pumped per kilowatt hour. With the pump running, determine the average total head in feet (including suction) against which the pump works. From the table secure the number of gallons which would have been pumped at the head if the installation were 100 per cent efficient. Divide the number of gallons actually pumped per kilowatt hour by the theoretical value given in the table. This gives the overall wire to water efficiency of the installation. To illustrate:

Assume a monthly pumpage of 18,620,000 gals., a total head of 200 ft., and a power consumption of 20,000 kilowatt hours. Dividing 18,620,000 by 20,000 we get 931 gals. per kilowatt hour. For 100 per cent efficiency the tables indicate that the discharge would be 1,592 gals. against a head of 200 ft. Dividing the actual discharge per kilowatt hour by the theoretical value we have: $\frac{931}{1{,}592} = 58.5$ per cent overall efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or other convenient period of time. During this period measure the output of the pump with a pitometer, or any other suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for 10 or 20 minutes the rate of power input can be closely ascertained. Or the power company might measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, this latter method is the only feasible one.

To enter the tables, the total head in feet must be secured. If the pressure gauge reads in pounds, transfer the pressure to feet by multiplying the pounds of pressure by 2.31. The suction will probably be expressed in inches of mercury. Change this to feet of water by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the addition of:

Discharge pressure, in feet .....
Suction, in feet .....
Vertical distance pressure gauge (Is above point of suction measurement), feet .....

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump works against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value secured from the table for the head against which the pump worked. This gives the overall wire to water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

K.W. input to motor 90.0
Rate of discharge..... 51,480 gal. per hour
Number of gallons delivered per k.w.h..... 572

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,373	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	143	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

*The Pitometer Co., New York City.
[1]From WATER WORKS AND SEWERAGE.

Pressure	146 lb. or 337 ft.
Suction	15 in. or 17 ft.
Difference in gauge elevation	1 ft. 1 ft.
Total head	355 ft.
Theoretical discharge 355 ft. head (tables)	897 gal.
Overall efficiency	$\frac{572}{897}$ = 64 per cent

. Provided a suction gauge is not available an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about one foot for loss in bends, etc.

Results of Checking Efficiency

The solution of each instance of inefficient operation is a problem in itself. No hard and fast rule for procedure can be given. In the case cited of obsolete design, the economical procedure was to replace the pump with one of modern design, keeping the old unit as a standby. In other instances, a change in the impeller will often return the pump to high efficiency. In one case, where a multiple stage pump was working against a high head, it was found that its inefficiency was caused by a defective gasket between the upper and lower parts of the pump case. This permitted the water to flow back from the higher to the lower stages, thereby decreasing both the rate of discharge and the efficiency. A new gasket was all that was necessary to solve the difficulty. In another instance, it was found that some of the ports had become plugged with wood, probably when a filter bed had broken three years previously. At least once, an impeller was found loose on the shaft.

About two years ago, an instance was uncovered where an apparent inefficiency was due to the power meter being set high. As soon as the test figures were in, the striking thing was not so much the low efficiency indicated, as the fact that the motor was apparently taking power at a rate which would have caused it to "burn up" from over-loading.

This list could be prolonged almost indefinitely, but it is believed that enough illustrations have been given to show the value of continuous checks. Many progressive operators show on their monthly or weekly reports the number of gallons pumped for the period for each kilowatt hour of power consumed. This is a splendid practice. Whenever our company, in making these tests, has found a low efficiency indicated, our experience has shown that the power companies and the pump manufacturers are most willing to cooperate in restoring the plant to efficient operation.

Assuming that the motor is about 90 per cent efficient, the following overall wire to water efficiencies may be expected from centrifugal pumps of good design:

g. p. m.	Per cent
200	49
400	54
600	58
800	60
1000	63
1500	67

More expensive pumps of best design will often show values of three to five per cent higher than the above figures.

In order to illustrate how the table can be used to compute probable savings to result from the substitution of a more efficient unit for an existing inefficient one, let us assume that 1,000 g.p.m. are being pumped against a total head of 200 ft., and a discharge of only 796 gal. per k.w.h. is secured. This gives us $\frac{796}{1592}$ = 50 per cent efficiency. Should this installation be replaced by one capable of an overall efficiency of 65 per cent, we would get 1,592 × 65 per cent = 1,035 gal. per k.w.h.

With an assumed monthly pumpage of 30,000,000 gal., it would require, with the original installation, $\frac{30{,}000{,}000}{796}$ = 37,676 k.w.h. to pump the water.

With the proposed more efficient installation it would require $\frac{30{,}000{,}000}{1{,}035}$ = 28,986 k.w.h.

This is a saving of 8,690 k.w.h., or 23 per cent, in the actual power consumption. There is also a similar decrease in the demand rate. The pumping rate of 1,000 g.p.m. equals 60,000 g.p.m.

$$\frac{60{,}000}{796} = 75 \text{ k.w. demand rate}$$

and

$$\frac{60{,}000}{1{,}035} = 58 \text{ k.w. demand rate.}$$

This is a decrease of 17 k.w. or 23 per cent in the demand rate. Both the demand rate and the actual consumption of power are therefore decreased in the same proportion. If the power cost averages 2 ct. per k.w.h., the reduction amounts to 8,690 × 0.02 = $173.80 per month, or $2,085.60 per year.

A word of warning may not be amiss here. While the large pumps are more efficient than the smaller ones, pumps larger than actually required should not usually be used. Often the additional friction loss due to higher velocity will offset the increased efficiency, and the higher demand charges will boost the total bill considerably.

Assume an installation which consumes 12,000 k.w.h. per month and which has a demand schedule as follows:

5,000 k.w.h. @ 0.030c	$150.00
5,000 k.w.h. @ 0.026c	130.00
2,000 k.w.h. @ 0.012c	24.00
Total	$304.00

If we use a smaller installation with half this demand rate we might use 13,000 k.w.h. per month to pump the same amount of water, but the total bill would be less:

2,500 k.w.h. @ 0.030c	$ 75.00
2,500 k.w.h. @ 0.026c	65.00
8,000 k.w.h. @ 0.012c	96.00
Total	$236.00

This is a saving of $68.00 per month although more power is actually consumed. And, after all, the object in securing increased efficiency is to pump more water per dollar.

Measuring Output of Water

Table I previously given has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. If a curve for the pump is not available and if the manufacturer cannot supply one, approximate results can be obtained by using the efficiencies previously given in this paper. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available. As a matter of fact, in one instance where this method was used to check the master meter, it was found that it would have been impossible for the pump to have delivered the water shown on the master meter unless the installation had an efficiency of about 125 per cent. This, of course, would be impossible. Whenever a pump installation gives an efficiency over 100 per cent, the secret of perpetual motion will have been discovered. In the case just cited, the master meter was about 100 per cent fast.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

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The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

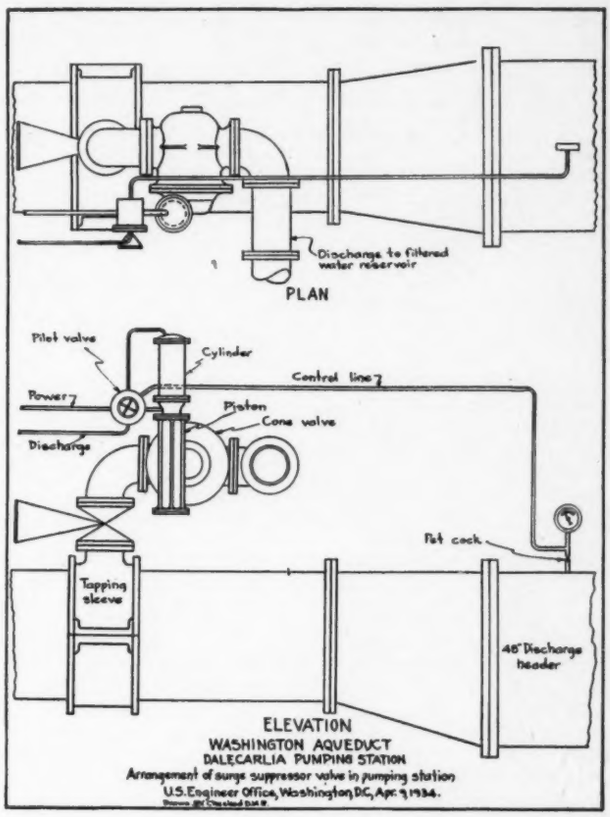

Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

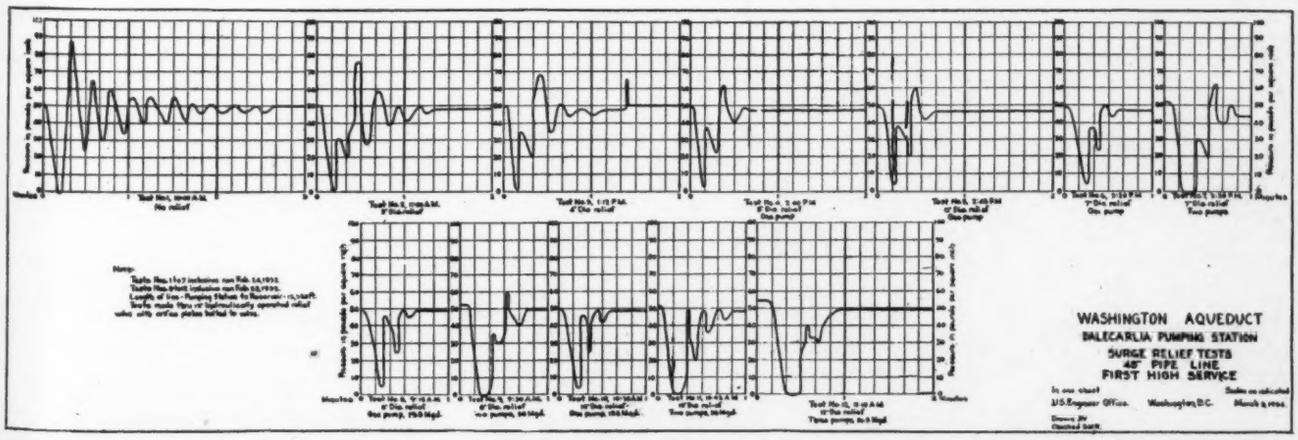

Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

*From WATER WORKS AND SEWERAGE, May, 1934.

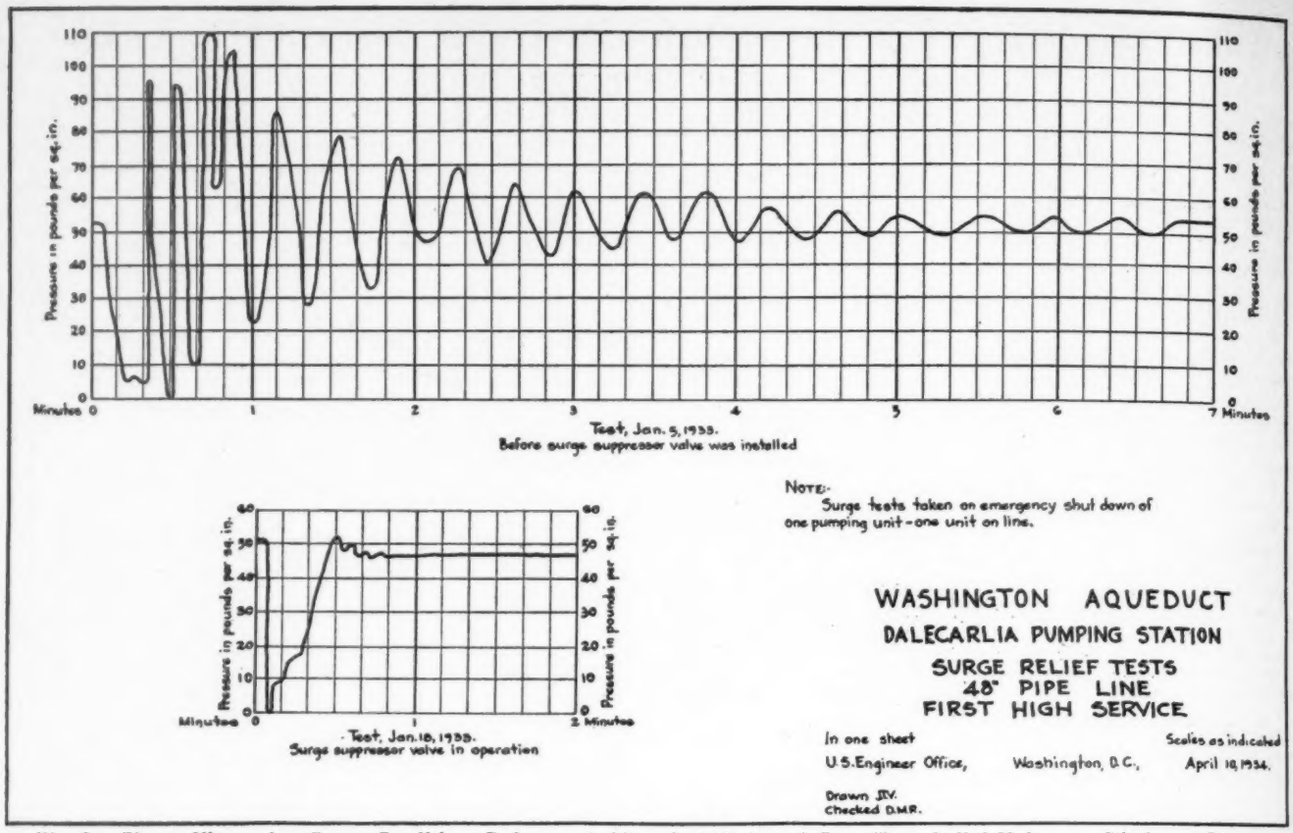
Pressure in pounds per sq. in.
Minutes
Test, Jan. 5, 1933.
Before surge suppressor valve was installed
Test, Jan. 18, 1933.
Surge suppressor valve in operation
NOTE:-
Surge tests taken on emergency shut down of one pumping unit - one unit on line.
WASHINGTON AQUEDUCT
DALECARLIA PUMPING STATION
SURGE RELIEF TESTS
48" PIPE LINE
FIRST HIGH SERVICE
In one sheet
Scales as indicated
U.S. Engineer Office, Washington, D.C., April 18, 1934.
Drawn JIV.
Checked D.M.R.

Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

SEWAGE AND SLUDGE PUMPING[1]

By HENRY RYON[2]

Albany, N. Y.

General

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

[1]From a paper presented before the N. Y. State Sewage Works Ass'n.—1935.

[2]Senior Sanitary Engr., N. Y. Dept. of Public Works.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a common suction header must for the same reason be made

at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Sludge Pumps

Both centrifugal pumps and reciprocating pumps have been successfully used for pumping sludge. Where the quantity of sludge is large, the centrifugal pumps with suitable non-clogging impellers are probably the more satisfactory. In many cases, such as pumping sludge from the bottom of a settling tank, it is desirable to draw the sludge slowly and regulate the rate carefully to prevent drawing the upper layer of fresh sludge, or even the supernatant liquid through the digested sludge in the bottom of the tank. Except in the largest sewage disposal plants this may be difficult with a centrifugal pump. If a small sized pump is used, it is apt to clog. If a large sized pump is used it will generally be necessary to decrease its capacity at times. Throttling the discharge of a sludge pump for this purpose is obviously undesirable. Motors with variable speed transmissions by means of which the pump speed may be varied without varying the motor speed, while rather expensive, may be used very satisfactorily for this purpose. Centrifugal sludge pumps must of course be set below the water level in the suction well if priming difficulties are to be avoided.

For the above reasons the reciprocating pump is probably better adapted for sludge pumping in small sewage disposal plants. Where the lift is high and it is not necessary to vary the capacity, the ordinary single acting triplex pump, with ball valves, has proved very satisfactory. Where the lift is low and it is necessary to vary the flow, as is usually the case, the diaphragm pump or the plunger pump with large diameter cylinders, designed especially for handling sludge, is usually preferable. The present tendency seems to be toward the use of the plunger pump in preference to the diaphragm pump. At the Hudson River State Hospital sewage disposal plant, where the 10-inch diaphragm pumps are used about three hours daily, the diaphragms have to be renewed every six months.

On the other hand, at this same plant, where 10-inch plungers are used, the packing, under continuous operation, has to be renewed every three months. These pumps may have one or more cylinders. The pumps with two or more cylinders give a more even discharge and also a more nearly even load on the motor, but the single cylinder pumps serve satisfactorily in most cases. Where lime is fed into the pump suction the surge in the suction line caused by the single cylinder pump sometimes causes trouble. Different capacities may be obtained with these pumps by varying the length of the stroke. This is done on some pumps by using an eccentric on the main shaft which is adjustable to give any stroke from zero to the maximum. On the other pumps several holes are provided in the crank so that the stroke may be changed by inserting the connecting rod pin in the proper hole. In some cases two and three speed motors have been provided with pumps of this type to further increase the possible number of capacities. The stroke of a diaphragm pump can generally be varied from 0 to 3 inches while that of a plunger pump can generally be varied from 2 to 5 inches. Shear pins are usually provided to release the motor should any hard material stop the plunger. It is well to keep the speed of reciprocating pumps rather low if smooth operation is desired. Speeds of over 30 or 35 revolutions per minute will usually cause vibration although manufacturers often recommend higher speeds. The valves may be of the ball or of the flap type. The ball valves usually show less tendency to collect solids than the flap valves, but are not entirely free from clogging. Rags will pack under the balls and sometimes clog the valve chamber entirely. Special easily removable caps are generally provided on the valve chambers so that the valves will be readily accessible for cleaning. In this connection it might be well to note that if an air chamber, or alleviator, is provided on the discharge line the discharge shut off valve should be between the air chamber and the pump or a special drain valve provided for the air chamber. Otherwise the sludge in the air chamber will be blown out through the discharge valve chamber when the cap is removed for cleaning or repairs. Pumps of the reciprocating type need not be set as low as centrifugal pumps because they prime more readily.

Friction of Sludge in Pipe

Where the suction and discharge lines are long it is often necessary to consider the friction loss in the pipes when the sludge is passing through them. Considerable has been written on this subject but there is as yet no standardized formula for computing the loss. The loss for a sludge with a high water content is about the same as for water but increases as the water content decreases until it often reaches 1½ times the loss for water. The loss is sometimes figured by using a coefficient of 60 or 70 in Chezy's formula instead of the 100 usually used for water.

Motive Power

At the present time most pumps are driven by electric motors. It was customary a few years ago to provide auxiliary gasoline engines as a source of power when the electric power failed. Usually, however, when the electric current failed, the service was restored before the operator could start his neglected gasoline engine. With the use of underground transmission lines and inter-connected power stations, failure of electric current has been so reduced that the auxiliary engines are now being omitted in most stations. Gasoline engines, oil engines and steam engines can, however, be used satisfactorily for driving pumps where electric current is not available.

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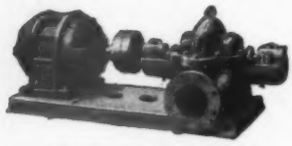

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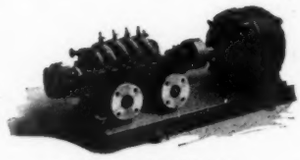
Modern precision methods of manufacture, with careful shop testing of each unit insure satisfactory performance, high efficiency and long life.

Complete details are given in bulletin No. 408. These pumps are also furnished for series operation and for gasoline or diesel engine drive.



MULTI-STAGE PUMP

Horizontally split case multistage pumps suitable for high pressure water supply with drive from motor, gasoline engine or turbine. Available for heads up to 1000 ft. Construction is heavy for continuous service.

High efficiency over a broad range gives these units very desirable performance characteristics. Complete details of these units are given in bulletins Nos. 414 and 426.

VERTICAL DIRECT CONNECTED SEWAGE PUMP

OPEN SHAFT SEWAGE PUMP

Horizontal or vertical non-clogging pumps for capacities up to 20,000 G.P.M.

Heavy construction for handling unscreened sewage or liquids with large solids. Standard impellers pass solids 2" to 12" dia., depending upon pump size.

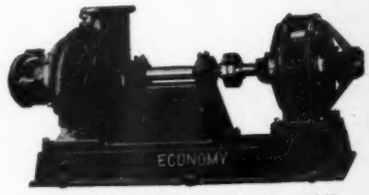
The first Economy sewage pumps, made over twenty years ago, are still giving satisfactory service. The Economy sewage pump of today is a highly developed unit, a result of long experience in this field.

Horizontal units are available in both solid shell and angularly split design.

All units are ruggedly constructed with heavy oversize alloy steel shafts, ample heavy duty bearings, patented shock absorber, and are well designed hydraulically for high operating efficiencies. Vertical units are also offered in two styles, i.e., the regular open shaft design where the prime mover is some distance above the pump, and the new vertical direct connected unit with motor mounted directly on pump with flexible coupling drive (*not* close coupled).

Complete details of these units are given in bulletin No. F-434 horizontal pumps and No. F-534 vertical pumps.

HORIZONTAL SEWAGE PUMP

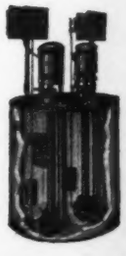


SPLIT HORIZONTAL SEWAGE PUMP

SUBMERGED TYPE NON-CLOGGING PUMP

Economy Sump Pumps and Sewage Ejectors are made in general service or non-clogging design. The non-clogging pumps handle sewage, rags, stones, etc. A number of interesting improvements have been made in these pumps to lengthen life and reduce maintenance cost. These features, together with complete capacity tables, are contained in Bulletins Nos. E-836 and 427. These pumps are available in capacities up to 5000 G.P.M. with heads up to 120 ft. Illustrations show both single and duplex units.

A PUMP FOR EVERY PURPOSE

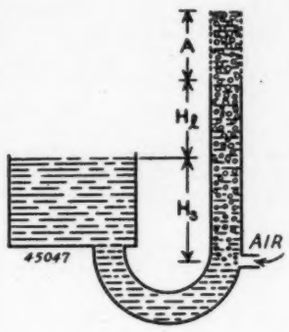


DUPLEX SUBMERGED TYPE NON-CLOG PUMP

PUMPING BY AIR LIFT*

Principle

The method of pumping with compressed air can be illustrated by the drawing at the right.



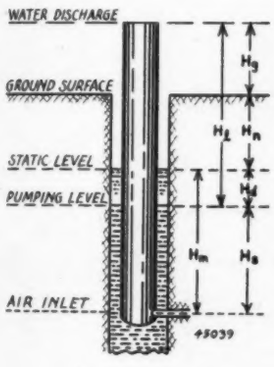
If the tank is filled with water, it is clear that it will rise in the vertical column to the same level as in the tank. Now assume that a specific quantity of compressed air is allowed to continuously flow into the pipe. The mixture of air and water in the vertical pipe, because it is lighter than the water in the tank, would rise a distance of $H_1 + A$ above the water in the tank. This is true because the light mixture of air and water in the column $H_s + H_1 + A$ just balances the head of pure water "H_s" in the tank. With this condition, no water is flowing, since the system has reached a static position. Assume that, after the static position has been reached, a section of the pipe is cut off, say "A" amount. Now, the mixture of air and water in the column no longer balances the head of pure water in the tank and the result is a flow of water up the vertical column. The actuating force is equal to the unbalanced force of the column of mixture due to deducting "A." This actuating force is equal to the pressure exerted by the head of pure water H_s (submergence) less the pressure exerted by the head of the mixture H_1 (lift) + H_s (submergence).

Terms

H_g = Distance from ground level to point of discharge = Lift above ground in feet.

H_n = Distance from the water level to the ground level when the well has been allowed to stand for some time without pumping = Static lift in feet.

H_d = Distance from the water level when the well is pumping the desired quantity of water to the water level when the well is not pumping = Drawdown at required water capacity in feet.



H_1 = Distance from pumping level to point of discharge = $H_g + H_n + H_d$ = Total lift in feet.

H_m = Distance from entrance of air into discharge pipe to the static or normal water level = $H_d + H_s$ = Starting submergence in feet.

H_s = Distance from entrance of air into discharge pipe to the pumping water level = Working submergence in feet. This factor is often expressed as per cent submergence which is

$$\frac{100\ H_s}{H_s + H_1}$$

*Courtesy, Ingersoll-Rand Co.

Data Used in Air Lift Calculations

Quantity of Air Required

$$V_a = \frac{H_1}{C \log_{10} \frac{H_s + 34}{34}}$$

in which

V_a = cubic feet of free air per gallon of liquid.
H_1 = total lift in feet.
H_s = working submergence in feet.
C = factor varying with submergence; given below.

Submergence	Value of C outside air line	Value of C inside air line
75%	366	330
70%	358	322
65%	348	306
60%	335	285
55%	318	262
50%	296	238
45%	272	214
40%	246	185
35%	216	162

Submergences

Lift in Feet	Customary Allowable Submergence Percentage	Best Submergence Percentage
20 to 125	50 to 70	65-70
125 to 175	40 to 65	60-65
175 to 250	40 to 60	55-60
250 to 350	37 to 55	50-55
350 to 650	37 to 50	45-50
650 to 750	35 to 45	40-45

Size of Discharge Pipe

$$d = 13.54\sqrt{\frac{Q}{v}}$$

in which

d = inside diameter of pipe in *inches.*
Q = Volume of the mixture of air and water in cu. *ft.* per min.
v = velocity of mixture in pipe in *ft.* per min.

With a straight pipe the best discharge velocity of the mixture of air and water for lifts from 40 to 200 ft. varies from 2000 ft. per min. at 35% submergence to 700 ft. per min. at 70% submergence.

With a tapered pipe the best discharge velocity is 1400 ft. per min. at 35% submergence and 550 ft. per min. at 70% submergence. The best velocity for the mixture of water and air at the entrance to the bottom of the discharge pipe is 800 ft. per min. at 35% submergence and 450 ft. per min. at 70% submergence.

Starting Pressure

$P_s = 0.434\ H_m$

in which

P_s = starting pressure in lbs. per sq. in.
H_m = starting submergence in feet.

Working Pressure

$P_w = 0.434\ H_s + P_f$

in which

P_w = working pressure in lbs. per sq. in.
H_s = working submergence in feet.
P_f = friction drop in air line from the compressor to the foot piece in lbs. per sq. in.

PIPE LINE FRICTION COEFFICIENTS

A Summary of the Findings of the Committee on Pipe Line Friction Coefficients*

The voluminous report embracing data collected and compiled by the above committee has been printed in the September, 1935, *Journal* of the New England Water Works Association, and is available in the form of reprints.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract, prepared by E. T. Killam, chairman of the Committee.

The general conclusions drawn from the data submitted to the Committee are as follows:

1. The average *actual* loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52 per cent.

The loss *predicted* in the Williams-Hazen tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 per cent.

2. Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation is applicable primarily to large-diameter mains carrying relatively inactive water.

3. For small-diameter mains carrying active water, the actual *loss* after 30 years may be twice the Williams-Hazen *predicted* loss.

4. Other factors being equal the data show marked correlation between pH value of water carried and rate of capacity loss, average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.

Scope of Report

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried, and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

Precision

The Committee has endeavored to compile mass data of reasonable precision; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented includes only such data as have been considered to fall within the limits of reasonable precision set by the Committee.

This policy of precision applies particularly to the presentation of various "trend curves," which is the designation adopted for expressing the age-coefficient relation. These "trend curves" in which values of C have been plotted against the age of the pipe in years, have been presented only in cases for which numerous tests of reasonable accuracy were available.

In considering these trend curves it should be emphasized that the results represent actual field tests and accordingly include all incidental losses due to irregular line or grade, and due to fittings or special castings.

Use of Williams-Hazen Coefficient "C"

The Williams-Hazen formula has been used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the following formula:

$$v = C\, r^{0.63}\, s^{0.54}\, 0.001^{-0.04}$$

v = Velocity in feet per second
r = Hydraulic Radius in feet
s = Hydraulic slope in feet per foot
C = The Williams-Hazen Coefficient

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 per cent.

Coefficients of Tar-Coated C. I. Pipe

Tar-coated cast iron pipe has been more widely used in water works practice than any other type of pipe, and a discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for new pipe becomes a fundamentally important assumption. The values of C for new tar-coated cast iron pipe adopted in the report are as follows:

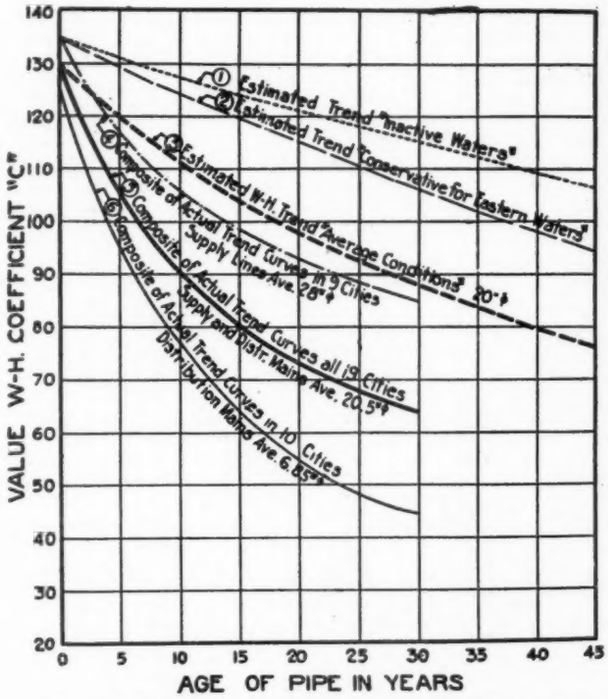


Fig. 1.— Summary of Estimated and Actual Trends of Age-Coefficient Relation for Tar-Coated Cast-Iron Pipe.

***Curves* 1 *and* 2 are based on data for steel pipe (U. S. Dept. of Agriculture, Bull. 150, 1930).**

***Curve* 3 is based on the Williams-Hazen Tables for average soft unfiltered river water.**

***Curve* 4 is a composite for supply and transmission lines 16 in. or larger in diameter.**

***Curve* 6 is a composite for distribution mains less than 16 in. in diameter.**

***Curve* 5 is a composite of Curves 4 and 6. Composite curves are based on arithmetic averages.**

Actual vs. Estimated Losses in Main Capacities with Age Increase Summary Curves Taken from the Report of the Committee of N. E. W. W. A. on Pipe Line Coefficients

*Presented before the New England Water Works Association September 17, 1935.

For supply and transmission mains 16 inch and larger in diameter ..... C = 135
For distribution mains less than 16 inch in diameter, with allowance for Ts, valves, bends, corporation cocks, or other specials involving friction loss..... C = 125

Variations possibly approaching 10 per cent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast iron pipe with age, (other than the convenient, though inadequate, assumption that C = 100) is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen predicted age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with actual trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes a total of 473 tests in 19 different cities. These data, results of which have not heretofore been published, have been classified and are presented in the form of trend curves.

These trend curves, as in the assumption of values for new pipe, have been segregated into two major classifications, namely, for supply and transmission mains 16-inch and over in diameter, and for distribution mains less than 16-inch in diameter.

Further classification has been made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

Summary of Data on Actual Capacity Loss in Tar-Coated C. I. Pipe

The data on actual loss of capacity in tar-coated C. I. mains may be briefly summarized, as follows:

Supply lines in nine cities showed a loss after 30 years of 37 per cent as compared with a predicted Williams-Hazen loss of 30 8 per cent.

Distribution mains in ten cities showed an actual loss in 30 years of 64 per cent as compared with a Williams-Hazen predicted loss of only 37 per cent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6-inch to 48-inch in diameter, with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 per cent, as compared with a predicted loss of 32.3 per cent for pipe of the same diameter.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to large diameter mains carrying relatively inactive water—and do not represent "average conditions."

Quality of Supply and Its Effect on Capacity Loss

The wide variation in rate of capacity loss in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting data, the Committee has accordingly attempted to consider the quality of supply and its effect upon rate of capacity loss.

Alkalinity and carbon dioxide have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the per cent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the supply.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH Value of Supply	Approximate Average Per Cent Capacity Loss in Tar-Coated C. I. Pipe (In 30 Years)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

Capacity Loss in Tar-Coated C. I. Pipe Due to Special Causes Other Than Tuberculation

Although tuberculation is most frequently the cause of loss of capacity in tar-coated cast iron mains, certain cases included in the Committee data afford examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss are quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss are: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

Coefficient Values of Cement-Lined Pipe

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients, are discussed.

Accordingly a second section of the report is devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe are limited in scope and widely scattered in the literature. Accordingly, all available data have been compiled and presented in order that they may be made more readily available.

The Committee data indicates that the average value of C for new pipe, 4-inch to 24-inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicate that at least for mains 24-inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement linings not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately a 10-year period, C = 136; for old style cement lined wrought-iron pipe 12-inch and 14-inch diameter, after 41 years of service, C = 104.

Available data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service, also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with tar-coating.

Coefficient Values of Pipe with Bitumastic Enamel Lining Centrifugally Applied

A third section of the report is devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10, 12, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining (centrifugally applied) may vary from C = 145 to C = 160 with an average value of C = 155; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this style of lining, may vary from C = 140 to C = 150 with an average valve of C = 145

Bitumastic enamel lining is ordinarily applied with a thickness of only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data is available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicate no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

Application of Linings to Mains in Place

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of

abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

Corrective Treatment

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with respect to calcium carbonate, it will be practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium bi-carbonate, (alkalinity) of the water and its magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH that must be maintained with another supply.

Restoration of Capacity of Unlined Cast Iron Mains by Cleaning

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report: First, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning. Second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicate that cleaning will ordinarily restore mains to approximately 85 per cent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 per cent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

Summary of Appendices

All of the foregoing subjects deal directly with coefficents with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general questions of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

Coefficient Values of Steel Pipe

A discussion of coefficent values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when new.

The ordinary average values of Williams-Hazen C for various classes of new steel pipe may be summarized as follows:

Corrugated pipe	60
Spiral riveted flow against laps	100
Spiral riveted flow with laps	110
Full riveted	115
Girth riveted	130
Continuous interior pipe	139

Coefficient Values of Concrete Pipe

Available data on concrete pipe indicate an extremely wide range in values of C, with instances of values as low as $C = 85$ and as high as $C = 152$. This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete pipe, carefully manufactured, may be assumed to approximate $C = 150$. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

Summary

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report is based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

Upon the basis of the average data on tar-coated cast iron pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williams-Hazen tables. Otherwise expressed the value of C dropped to 88 after only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years' service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 per cent, as compared with a predicted loss of 37.5 per cent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It is hoped that these curves will serve to interest members of this and other associations in conducting and recording tests, in order that more selective numerical data may be ultimately made available to the profession.

Elson T. Killam, Chairman; Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

TREATING WATER TO PREVENT CORROSION*

By JOHN R. BAYLIS†

Associate Editor, Waterworks & Sewerage

The writer, in 1930, presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_3 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe

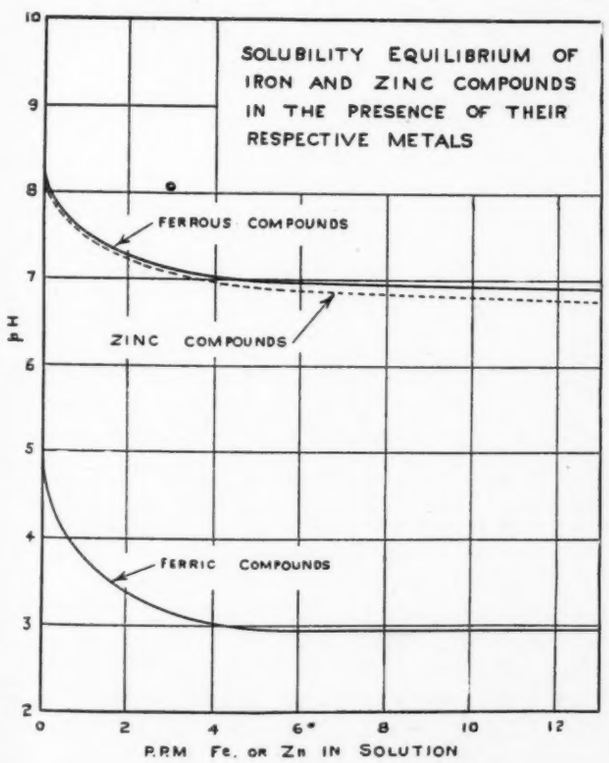

SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M Fe. OR Zn IN SOLUTION

Fig. 1

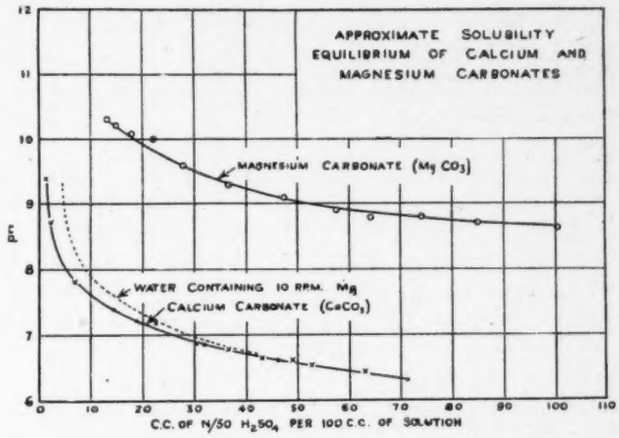

APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually desi[gn] the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

*Excerpts from an article which appeared in WATERWORKS AND SEWERAGE.

†Physical Chemist, Bureau of Engineering, Chicago, Ill.

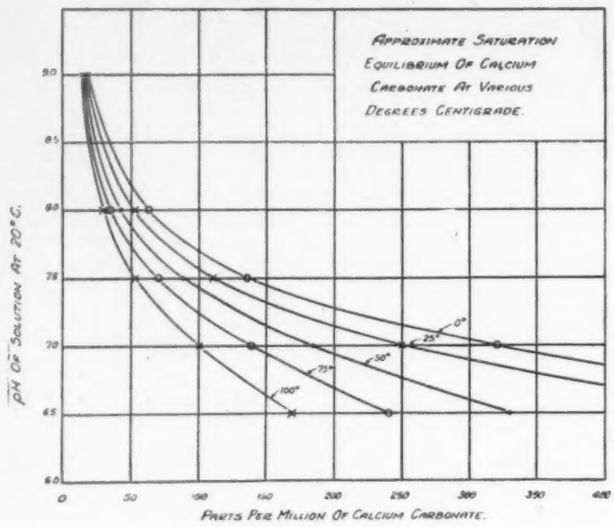


Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_2 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_2 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

percipitate. It will remain where it is precipitated to offer protection against further corrosion.

How to Determine If the Water Is Saturated with Calcium Carbonate.—The saturation equilibrium of calcium carbonate for various pH values has been determined fairly accurately where there are no other compounds to interfere. The writer has published a curve in several articles showing the approximate equilibrium as determined from actual tests. The equilibrium is affected by certain compounds that may be in the water, and for natural waters the best procedure is to determine the equilibrium by tests for the particular water. This is done by treating the water in a manner in which it is desirable to treat in a plant to the point where it is thought the treatment will make the water saturated with calcium carbonate. If lime is to be used in the plant, then the water should be treated with lime; and if soda ash is to be used, then this should be used in the test. Usually the water is already being treated with an alkali and it is only necessary to collect a sample of the water after treatment.

Place the water in contact with powdered calcium carbonate in a closed flask and agitate until equilibrium has been established. If a one-liter flask is used, place at least 200 grams of powdered calcium carbonate in the flask and wash several times with water the same as is to be tested. Fill the flask nearly full of the water to be tested, first determining its pH and alkalinity. If agitated constantly, the equilibrium should be established within 24 hours. When agitated frequently by hand, it should be kept up for about 3 days. The flask should be stoppered tightly so that CO_2 from the air will not affect the results. If either the pH or alkalinity changes, equilibrium has not been established. An increase in alkalinity indicates the water is not saturated and a decrease indicates that it has been supersaturated.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

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[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines. Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

DETERMINING THE NECESSARY TREATMENT TO PREVENT CORROSION*

By P. L. McLAUGHLIN

Sanitary Engineer, West Virginia Water Service Co., Charleston, W. Va.

Difficulties from red water and corrosion have necessitated corrective treatment at nine of the fifteen water works plants owned by the West Virginia Water Service Company in the State of West Virginia.

All nine of the supplies considered are purified in rapid sand filtration plants. Lime is applied to the filtered water in the clear water wells at seven of the plants.

Satisfactory experiences can be cited for the plants using corrective treatment. Without exception, the managers of these properties report that present conditions are far superior to those experienced prior to the use of the treatment. Practically no complaints of red-water are received by them today except occasionally from consumers residing on dead ends of the distribution systems. Furthermore, all managers report the presence of a white film, or protective coating, in the pipes of their distribution systems, although the extent to which this coating has been deposited varies with the different waters and seems to be dependent upon the size of the distribution system, the length of time the treatment has been in use and the accuracy with which it has been carried out.

The Method Adopted

The treatment consists of producing a plant effluent which is in "chemical balance"; that is, at the saturation point with respect to its power to dissolve calcium carbonate. This procedure is based on accepted principles that a water which no longer dissolves calcium carbonate should tend to form a protective coating in the mains and thus prevent corrosion. The writer uses the following procedure for rapidly determining, on a single sample of water, the correct pH to maintain through lime addition.

The procedure adopted assumes that the degree of undersaturation or the degree of supersaturation (within the limits required for performance of the test), of a water at a given alkalinity and pH is a function of the degree of increase or the degree of decrease in the total alkalinity of that water after contact with an excess of pure $CaCO_3$. Therefore, to determine the pH value at which the saturation point of an undersaturated water is attained, it is only necessary to increase the pH of a sample of that water (with lime) through a series of arbitrary pH values. Then, determine the degree of undersaturation, or supersaturation, as expressed by parts per million gain or loss in total alkalinity after treatment with $CaCO_3$, of the samples treated to produce increasing pH values. The use of a graph is then resorted to. The following example of the method as actually applied will illustrate the procedure.

*From WATER WORKS AND SEWERAGE—March, 1936.

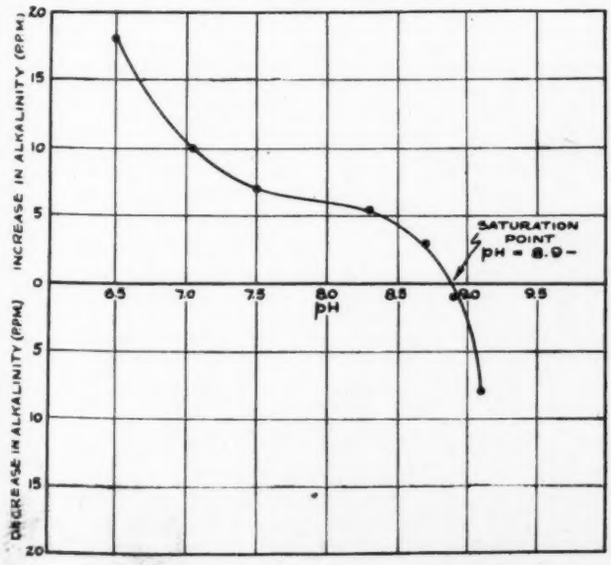


Fig. 1—Saturation Point of Charleston Filtered Water

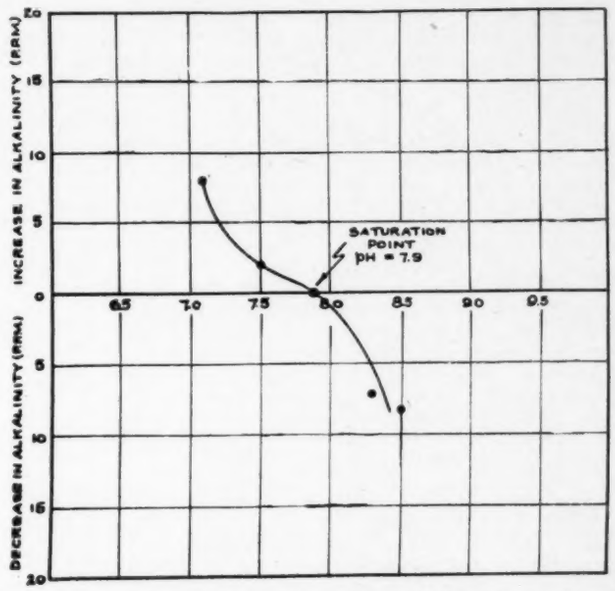


Fig. 2—Saturation Point of Nitro Filtered Water (Oct. 23, '35)

Test Procedure

A one gallon sample of filter effluent, taken ahead of plant treatment with lime, was collected in a gallon glass bottle. The pH of the sample was determined and found to be 6.5 and the total alkalinity (Methyl Orange) 18 p.p.m. About 200 c.c. of the sample was then transferred from the bottle to an Erlenmeyer flask. One teaspoon full of C.P. powdered (precipitated) $CaCO_3$ was added to the water in the flask and stirred for five minutes. The carbonate was then allowed to settle, after which the supernatant liquid was filtered through filter paper and the alkalinity determined on the filtered portion. This alkalinity was 36 p.p.m., an increase of 18 p.p.m. over that of the original sample in the gallon bottle. The increase in alkalinity was then plotted against the original pH value (6.5), thus determining the first point on the curve. (See Fig. 1.)

Hydrated lime in solution (lime-water) was then added gradually to the original sample in the gallon bottle and thoroughly mixed by stirring until the pH of the sample had increased to approximately 7.0—in this instance, 7.05. At this pH the alkalinity was determined on an unfiltered portion and found to be 24 p.p.m. A 200 c.c. portion of the sample was transferred, as before, to an Erlenmeyer flask; $CaCO_3$ was added, mixed for 5 minutes, settled, filtered and the alkalinity of the filtrate determined. It had increased to 34 p.p.m., representing a 10 p.p.m. pick-up of alkalinity from the carbonate as compared to an 18 p.p.m. pick-up in the first test on the unlimed sample. The second point on the curve was thus located, the increase in alkalinity of 10 p.p.m. being plotted against the pH of 7.05, which was that of the lime treated test sample.

More lime was then added to the water in the gallon bottle until the pH was raised to 7.5. At this pH value the alkalinity was 25 p.p.m. As before, a portion of the sample was removed and treated with $CaCO_3$, and an increase in alkalinity of 7 p.p.m. was observed. This increase was plotted against pH 7.5, forming the third point on the curve.

In a similar manner the pH of the sample in the bottle was raised with lime to pH values of 8.3, 8.7, 8.9 and 9.1 and the differences in alkalinities after treatment with $CaCO_3$ were plotted against each of these pH values.

It will be noted from the curve that at pH 8.7 the water was only slightly undersaturated, the increase in alkalinity after treatment with $CaCO_3$ being but 3 p.p.m. At a pH of 8.9, however, the alkalinity *decreased* 1 p.p.m. after treatment with $CaCO_3$, showing that at this pH the water was slightly supersaturated and some calcium alkalinity had deposited out on the suspended carbonate. Therefore, the exact point of equilibrium lay between these two pH values, or for all practical purposes at pH 8.9—see Fig. 1. The pH of the sample in the bottle was then increased to 9.1 in order to portray the trend of the curve more accurately.

Having determined the saturation point of the sample by the above procedure, its adaptation to plant control consists merely in adding enough lime to the filtered water to maintain a pH value of 8.9 or thereabouts in the plant effluent.

Inasmuch as free carbon dioxide gas (CO_2) influences the solubility of calcium carbonate in water, care should be taken in carrying out the procedure not to allow the sample to come in contact with the air any more than possible, and to avoid shaking or violent agitation of the sample. Removal of portions of water from the original sample should be made with a transfer pipette and a good grade of filter paper should be used for filtering the portions treated with $CaCO_3$. The procedure is carried out at room temperature and it is believed that a negligible error may be introduced thereby, since in the case illustrated the temperature in the Charleston laboratory was some 10 to 15 degrees higher than the temperature of the water in the clear well and in the mains.

A convenient and explanatory method of recording the data obtained in carrying out the procedure is shown below:

Filter Effluent—Charleston, October 17, 1935

pH 6.5 Alk. 18	$CaCO_3$ added, mixed settled and filtered	Alk. 36	Undersaturated +18
Lime added: pH 7.05 Alk. 24	$CaCO_3$ added, etc.	Alk. 34	Undersaturated +10
Lime added: pH 7.5 Alk. 25	$CaCO_3$ added, etc.	Alk. 32	Undersaturated +7
Lime added: pH 8.3 Alk. 27	$CaCO_3$ added, etc.	Alk. 33	Undersaturated +6
Lime added: pH 8.7 Alk. 28	$CaCO_3$ added, etc.	Alk. 31	Undersaturated +3
Lime added: pH 8.9 Alk. 32	$CaCO_3$ added, etc.	Alk. 31	Supersaturated —1
Lime added: pH 9.1 Alk. 35	$CaCO_3$ added, etc.	Alk. 27	Supersaturated —8

The Influence of Calcium Bicarbonate In the Water to Be Treated

It is known that when the calcium carbonate content of a water is less than 25 to 35 p.p.m., the calcium carbonate content must be built up to this amount before corrosion can be effectively prevented. The alkalinity of the water used to illustrate the procedure was but 18 p.p.m., and the water was therefore below the prescribed limits as to its calcium carbonate content. However, this deficiency was automatically taken care of in the procedure and in its adaptation to plant control methods by the use of lime which increased the calcium carbonate content to the point required for saturation. Several of the water supplies requiring corrective treatment operated by the West Virginia Water Service Co. normally, or occasionally, have calcium carbonate contents in excess of the minimum requirements. The procedure for determining the pH of the saturation point for these waters is carried out with lime in the same manner as described.

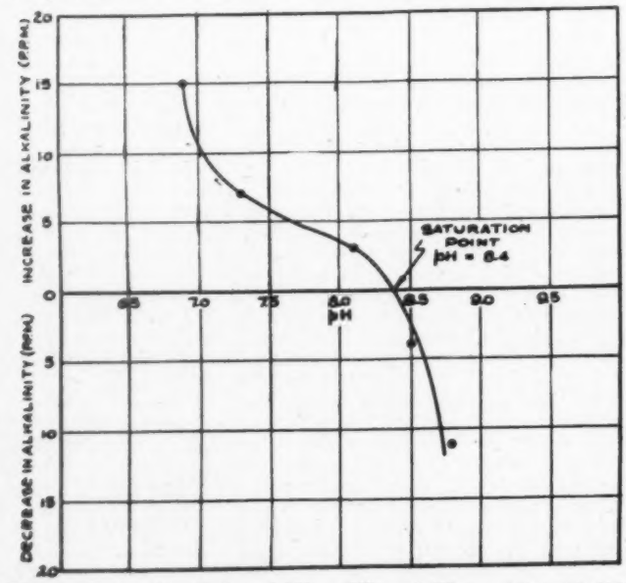


Fig. 3—Saturation Point of Nitro Filtered Water (Oct. 18, '35)

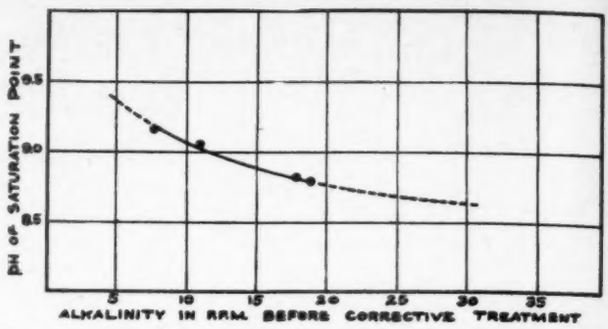


Fig. 4—pH Saturation Point vs. Total Alkalinity—Operating Curve

Figure 2 shows the curve obtained by the procedure on such a water. The sample was taken recently from the filter effluent of the Nitro plant which treats Kanawha River water and had a pH of 7.1 and an alkalinity of 47 p.p.m.

The saturation point of the same supply, determined five days previously, is shown by Fig. 3. In this case, the pH of the filter effluent before lime addition was 6.9 and the alkalinity was only 39 p.p.m.

Inasmuch as the pH of the saturation equilibrium with calcium carbonate of any water depends, among other factors, upon the concentration of dissolved alkaline compounds in that water, it has been found, as would be expected, that the pH of the saturation point varies with changes in the chemical composition of the water. As the alkalinity decreases, the pH and total alkalinity at the saturation point increases and vice versa.

Protective carbonate coatings will be quickly dissolved and removed if the water in contact with them is undersaturated. Also, such coatings will be built up too rapidly if the pH of the water is carried too high above the saturation point. Therefore, to practice effective control in the treatment for the prevention of red-water and corrosion on a supply of fluctuating chemical character it is necessary to vary the pH of the plant effluent as frequently as is required to meet changing raw water conditions.

A General Curve for Plant Control

For a given supply, saturation points (pH values) can be determined by the procedure for various alkalinity values and a saturation curve plotted from this data. Figure 4 represents such a curve under process of development for the Charleston water. With experience the number of trial tests can be reduced, and once the curve has been established for a supply, the approximate pH of the plant effluent of that supply required to bring the water to equilibrium with calcium carbonate can be selected at once by merely determining the total alkalinity of the water to be treated. Then, if desired, a single check test should confirm this value if made on the plant treated water.

When corrective treatment is first applied to a water supply it is probably best to deliver the water to the distribution system in a slightly supersaturated condition for a period of several months or until a thin protective film has been built up in the mains. The treatment should then be reduced and maintained as closely as possible at the pH of the saturation point with calcium carbonate. It will be found difficult, if not impossible, to maintain the pH at exactly the desired value under ordinary methods of plant control but the slight variations experienced should not impair the success of the treatment in so far as overall practical results are concerned.

In closing, it should be pointed out that the procedure presented in this paper is not held to be without errors but it is believed that the procedure provides a rapid and workable method, sufficiently accurate for the purposes required, whereby the pH of the saturation point of a water can be obtained from a single sample of that water, thereby eliminating cut and try methods on a plant scale. At least it has been successfully applied to the low alkalinity waters encountered in several West Virginia plants.

WATER SOFTENING*

by CHAS. P. HOOVER
Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

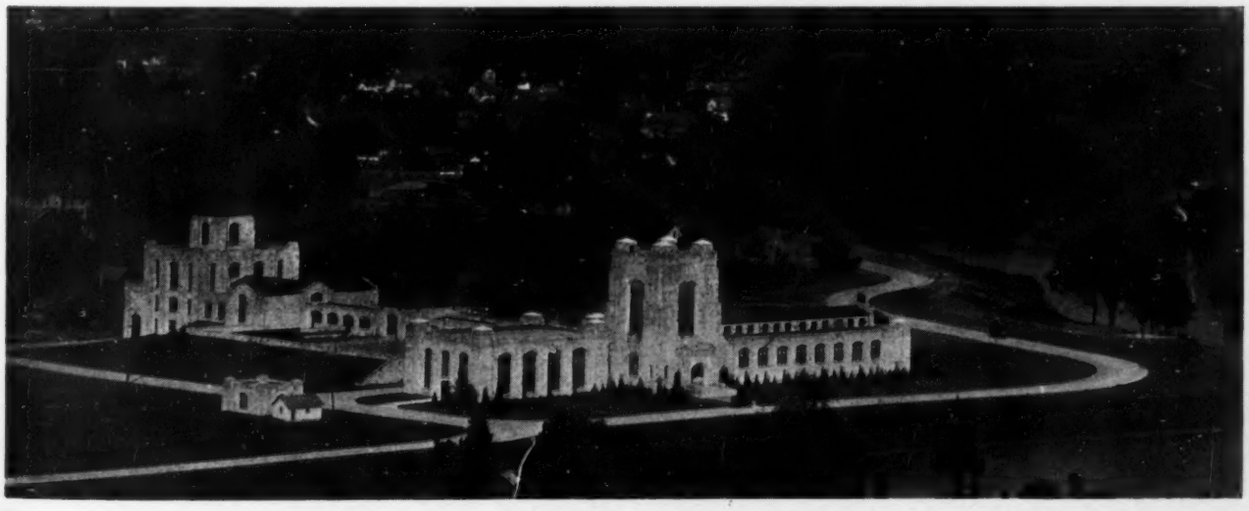
Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

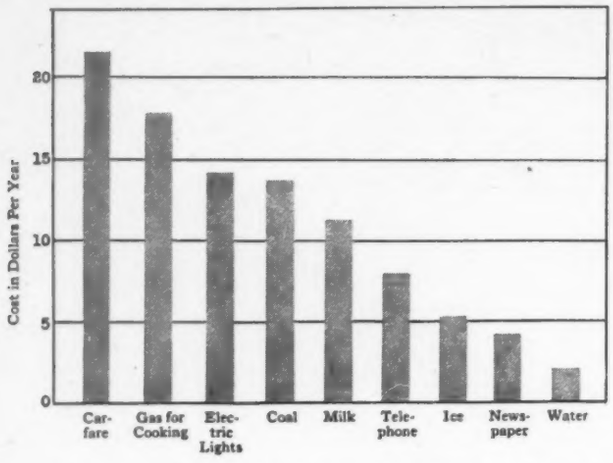
1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

*Ecerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.



America's Most Attractive Water Works Plant (WATER WORKS AND SEWERAGE *Contest*—1935) *and the Newest of American Softening Plants of Important Size*



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196.133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[2]Geological Survey of Ohio, Bulletin 29, 1925.
[3]Report of Water Commission, 1922.
[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show:

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stultifies Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

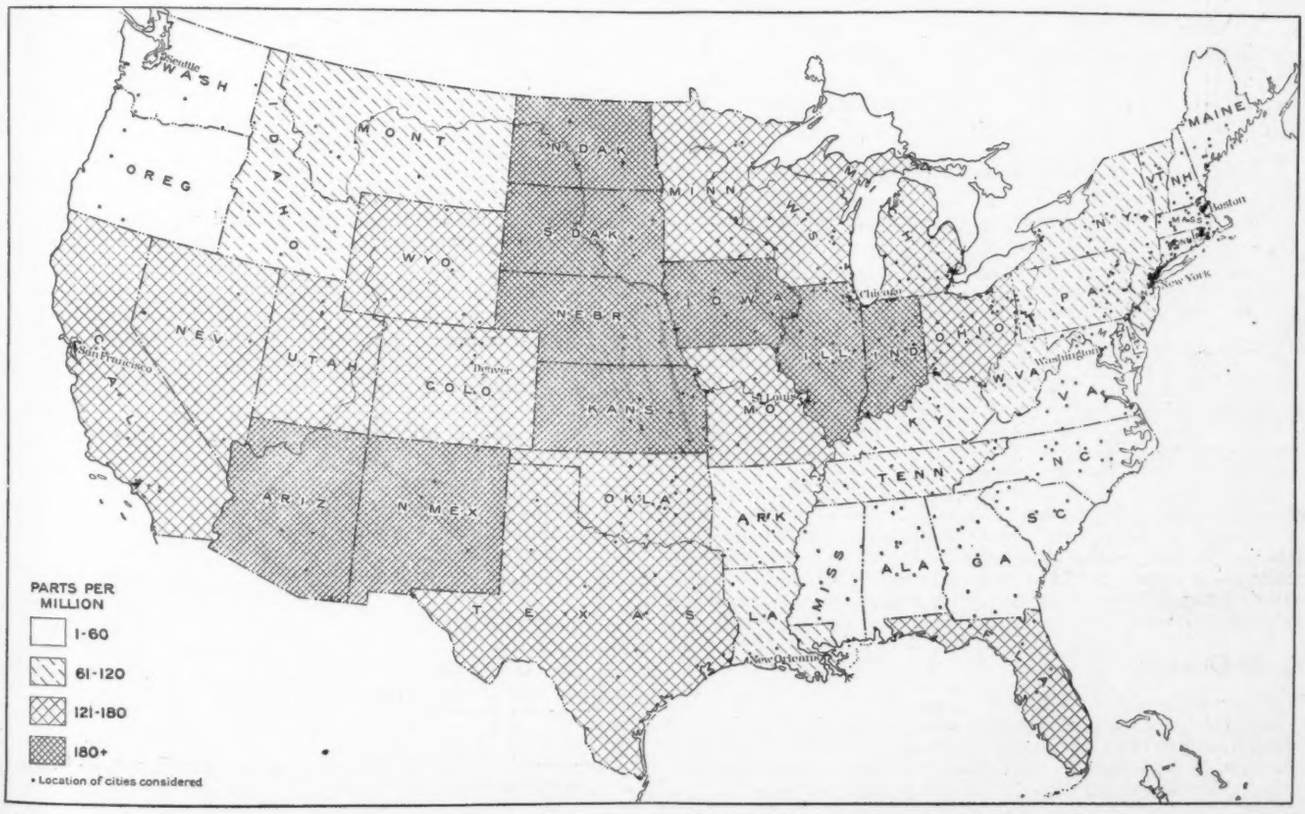
[7]Alvord, Burdick & Howson (Chicago), a private communication.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5]U. S. Bureau of Mines, Tech. Paper 218.
[6]Bulletin, American Railway Engineering Association, November, 1923.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

TASTE AND ODOR CONTROL PRACTICES

By F. E. STUART[1]

Taste and odor control is now second only to the production of a safe water. The cost has been studied carefully and has been weighed against its importance as a routine treatment.

Now that the economics of taste and odor control by applying large dosages of powdered activated carbon have been compared with the economics of closely controlled coagulation, involving carbon adsorption, a new flow scheme is becoming apparent. A combination of these two methods of treatment appears to be the most overall efficient and economical.

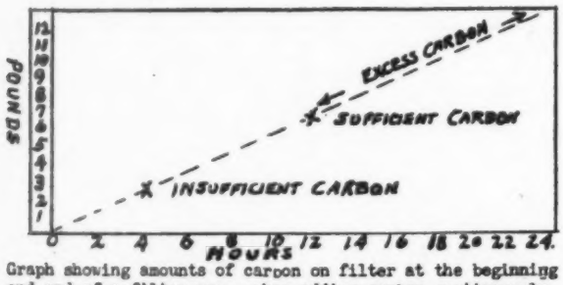
A short review is necessary to bring up to date the work that has been done on carbon by observers in the field. Further, to point out why this new type taste and odor control flow scheme is the most practical.

When alum is added to water and coagulation is produced, a large percentage of taste producing elements in the raw-water is precipitated in the settling basins. This is common practice and the effectiveneness coagulation is taken for granted.

Previous to the introduction of activated carbon, these precipitated impurities underwent decay and generated gases and liquids of decomposition, which contaminated the newly coagulated water passing through the basins. Putrefying and liquefying sludge in the settling basins is a more common cause of tastes and odors than generally realized. A high chlorine demand in the filtered water and of tastes in dead ends are created by the same phenomena. This is not difficult to appreciate when one remembers how badly the basins smelled when they were last cleaned.

Carbon in the Coagulation Stage

At Daytona Beach, Fla., Superintendent Tippins in 1931 found that carbon used in the coagulation process would inhibit bacterial activity in the settled sludge—resulting in odorless sludge and odorless filtered water. These findings were later confirmed by Furman at Toledo, Ohio, and Fitzgerald at Norfolk,



* Graph showing amounts of carbon on filter at the beginning and end of a filter run - when adding carbon continuously to the applied water - based on 12 pounds per million gallons and 24 hour filter run.

Va. This effect of carbon on coagulated sludge has become known as "Stabilization of Sludge."

Because of the good results obtained, other observers added carbon to the mixing chamber in dosages sufficient to remove the tastes and odors present,—dosages between 18 and 32 pounds per million being the most common.

Middlestadt in Sacramento, Cal., about this same time made a careful study of the amount of carbon needed to stabilize sludge and found this dosage to be very small—from 2 to 4 pounds per million gallons. In a recent survey 54 per cent of the plants now using carbon for taste and odor control have been adding small dosages of carbon to the mixing chamber to stabilize sludge and condition the filter sand.

Split Dosage

Later work showed a further reduction in the cost of carbon treatment by utilizing a split treatment; adding half of the total carbon dosage to the mixing chamber and half to the water flowing to the filters. More complete taste control has been accomplished thereby.

[1]Water Purification Division—Activated Alum Corporation, New York, N. Y.

Comparing the results between large dosages of carbon added continuously to the water flowing to the filters, large dosages added to the mixing chamber and split treatment the last proved to be the most economical. This brought about the latest change in treatment practice—adding the total amount of carbon to each filter after washing (about 4 to 6 pounds per million gallon filter area) and the addition of sufficient carbon to stabilize sludge and condition the filter sand, along with the alum dosage. A convenient method of doing the latter is to utilize the ready prepared activated alum which contains the required quantity of powdered carbon.

The floc produced by activated alum is more easily controlled than ordinary alum, because of the millions of tiny activated carbon particles which assist in the formation of the floc. A stable sludge will result and stable filter sand also, because the carbon particles are distributed throughout the floc. The floc does not break down as easily as ordinary alum floc and it has been found that less residual alumina is present in filtered water when activated alum is used.

Filter Dosing

Individual observers, led by Smith at Richmond, Va., showed reason why carbon should be added in one "Shot" dosage to the filter *after* washing instead of adding carbon continuously to the water flowing to the filter.

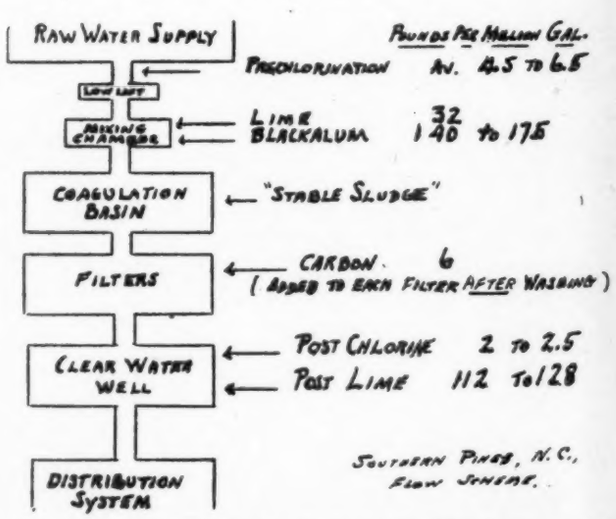
The common basic reasoning for such applications is that with carbon added continuously to the water flowing to the filters (we will say 12 pounds per million gallons), there is more carbon on the filter when it is taken out of service for washing than at any other time. Likewise, there is insufficient carbon on the filter for the first few hours of service, unless higher dosages than actually needed are applied. By estimating the amount of carbon actually needed for each run the dosage if added all at one time, produces a big saving in carbon. Average dosage of 4 to 6 pounds, per million gallons of filter area, seems to meet requirements between filter washings.

The following typical new type flow scheme for taste and odor control is used by Mills of the Southern Pines, N. C., Water Department:

Treatment	Pounds per Million Gals.		
Prechlorination	4.5	—	6.5
Lime, average	32		
Black-Alum (Activated Alum), average	140	—	175
Activated Carbon	6*		
Post Chlorine, average	2	—	2.5
Post Lime, average	112	—	128

This review points out why taste and odor control can be obtained more economically by means of good coagulation and car-

*Added to each filter following the wash.



Flow Scheme of Water Department, Southern Pines, N. C.

bon added to each filter immediately after washing—than high dosages of carbon at any one point in the treatment.

Carbon is now regarded as a routine treatment—to improve coagulation and remove tastes.

Carbon in the pretreatment through activated alum and the addition of 4 to 6 pounds of carbon per million gallon of filter capacity (added all at one time to the filter after washing) is now considered the most efficient and economical method. (See flow scheme).

For serious taste and odor epidemics which are only temporary, large dosages of carbon are necessary and should be applied as a split treatment.

Ammoniation

Suggested by Enslow and probably first introduced by Jordan at Indianapolis, Indiana, later adapted in many plants including Easton, Pa.; Trenton, N. J., and Fort Pierce, Fla., etc., the trend in ammonia application during the past year has been in connection with its use after filtration; it being added after the post-chlorine dosage.

This seems to be the most economical method of application because the dosage of ammonia used is that to combine with only the existing free chlorine.

Users of ammonia continue to favor anhydrous ammonia in cylinders because of ease of application and accuracy of control.

It is well known that ammonia, unless used in the proper concentration in the pretreatment, will in many instances increase algae growths along the sides of the settling basins. This increase in algae growth is controlled, however, if high dosages of ammonia and chlorine are used. These high dosages are uneconomical, and, therefore, prechlorination alone is generally adopted as the most economical practice; adding the ammonia after filtration.

Chlorination

The benefits of such a versatile product as chlorine cannot be outlined in more than a general way. Chlorine in the pretreatment is becoming more generally used, because prechlorination has several advantages in routine plant operation. All plants should have duplicate chlorinators for post-treatment and provisions for prechlorination.

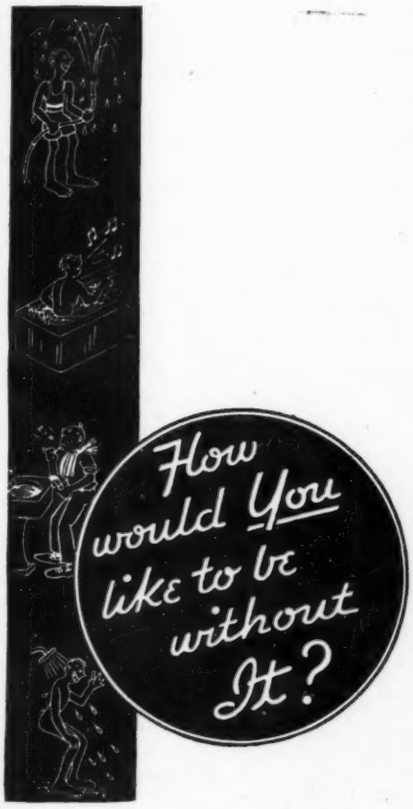
Experiences of the writer have been that high residuals in prechlorination are not advisable at any time. High prechlorination residuals hinder taste and odor control.

High prechlorination residuals are not necessary to improve coagulation or lengthen filter runs. Experiences of Fitzgerald at Norfolk, Va., show that the typical "water flea" can be stunned with prechlorination, without a residual reaching the filters. Prechlorination at the rate of 8 pounds per million gallons was just as effective as 30 pounds. The chlorination did not "kill," but "stunned" them to such an extent that the alum floc would precipitate them and then the filter runs lengthened out.

Many other experiences with chlorine in the pretreatment confirm the writer's opinion that it is a most useful tool to improve general plant operation, but should not be used in concentrations to produce high residuals in applied water. Especially is this true when dealing with algae tastes.

Acknowledgment: This article has been drawn largely from a paper read by the author before the Kentucky-Tennessee Section of A.W.W.A., March, 1936.

Lest They Forget!
(A Message to Consumers)



The Cover

"Pure water is the best of gifts that man to man can bring." —Lord Neaves.

The other day when I asked my little girl what water is she said, "It's what comes out when I open the faucet." This set me to thinking about how much all of us take for granted our water supply systems and the excellent service they give.

We have to be deprived of some things to realize what they mean to us. I have been thinking about our water works and what things would be like if it were to be permanently discontinued, if water no longer came from the faucet. The pictures aren't so rosy.

First, I would have to line up a source of water, for I could live but a few days without it. I would have to drill a well, collect rain water, or carry from a stream, pond or spring. At the best it would be a lot of expense or a lot of effort.

I would have to arrange to dispose of the sewage of my household. Again I run into expense and unpleasant conditions which are not nice to talk about.

It would be considerable more trouble to keep clean. Maybe the historic tub on the kitchen floor would have to be revived.

There would be no definite assurance that I would not be exposed to typhoid fever and other water-borne diseases which were such a scourge only a generation ago.

If my house caught on fire there would be much less chance of saving it and the other houses nearby. My family would not be so safe nor my sleep so peaceful.

Because of increased fire danger my insurance rates would jump, probably more than my total water bill. This is one advantage of water service most of us never think about.

In dry weather my lawn would turn brown and my garden would wilt for lack of water. It would be harder to wash my car, my front walk and even my dog.

After all, maybe we have let many years of "water from a faucet" dull our appreciation of a service which is so vital to our civilization and to our ability to live together in comfort, health and safety.

The Message

The above leaflet, prepared for sending out with the water bill to customers, has proven popular with water works superintendents and managers. It was the idea of the Ford Meter Box Co., of Wabash, Ind., who printed thousands of free distribution to its customers, after which additional orders were filled at the cost of wholesale production. Many favorable comments have been heard on its value. The question on the cover is the "attention getting element" which every publicity man recognizes as a first essential.

Don't let your customers forget the importance of the No. 1 Utility.

CHEMICALS AND MIXING*

Almost all surface water supplies are turbid, colored, and contain bacteria. The turbidity is due to finely divided matter held in suspension. It is usually too light to settle unless allowed long periods of time. Color is caused by dissolved organic material resulting from decayed vegetation and bacteria. Ordinarily these impurities may readily be removed by the use of coagulants.

Coagulating chemicals used in water purification dissociate when added to alkaline water to form a gelatinous, sticky precipitate which absorbs color and entangles mud, bacteria and suspended matter. By agitation (30 minutes to 1 hour) this gelatinous mass may be built up into flocs or clumps which are readily removed by settling. The coagulants generally used are ferrous sulphate and lime, ferric chloride, ferric sulphate, aluminum sulphate, sodium aluminate, and lime. These compounds are harmless to the consumer because they do not remain in the water. They are precipitated as insoluble compounds and removed by settling or filtration.

Ferrous Sulphate and Lime

A combination of ferrous sulphate and lime is an effective coagulant for the clarification of turbid waters. Both materials are relatively low in cost. They may be used in various ratios. Ferrous sulphate may be used alone for secondary coagulation if there is sufficient oxygen in the water to insure complete oxidation. Where prechlorination is practiced, chlorine may be used for this purpose. It oxidizes best at high pH values.

Ferric Sulphate

Ferric sulphate as a commercial product for coagulation is comparatively new. Its wide pH zone of coagulation makes it applicable to various conditions. Iron salts do not form soluble compounds in the alkaline range, and for that reason very low residual metal is found at the high pH values. Except in special cases of color removal, coagulation with iron salts is best at a pH of 9.0 or above.

Chlorinated Copperas

Ferrous sulphate is used as a base material for the preparation of chlorinated copperas. The ratio is one part of chlorine to eight parts of $FeSO_4 7H_2O$. In practice, usually about 10 per cent excess chlorine is used to insure complete oxidation. This material, which is essentially a continuation of ferric chloride and ferric sulphate, has proved effective. Results are best accomplished at pH below 7, due perhaps to complex ferric organic precipitates that are formed. Lime is used to adjust the pH to prevent corrosion, just before or after filtration.

Ferric Chloride

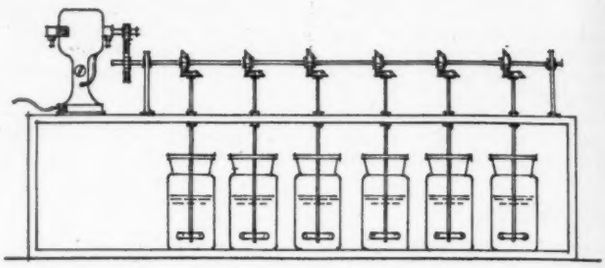
Ferric chloride has a high optimum pH zone of coagulation but can be used in low ranges for color removal. It is being used in water purification, but its greatest use has been as a precipitant and sludge conditioner in sewage treatment. Here a saving in ferric chloride on digested sludge is obtained by the use of lime, following ferric chloride treatment in amounts sufficient to raise the pH to 9.0 or more.

Aluminum Sulphate

Aluminum sulphate was perhaps one of the earliest coagulants used. It can usually be relied upon to give excellent results if the proper mix and conditioning are provided. The zone of best floc formation is at a lower pH than the iron salts. If used at its optimum pH of coagulation, low residual metal is found. It is very effective for reducing the normal carbonates, in many cases more than the theoretical amount. This property makes it especially valuable to some plants. Alum, to which about 2 per cent activated carbon has been added, has been recently put on the market under the name "Activated Alum." Its application thus far has been too limited to make conclusive remarks.

Sodium Aluminate

Sodium aluminate is more expensive than other coagulants. Its application for municipal plants has been limited. It is especially effective when used with lime and soda ash in the treatment of boiler feed waters. It forms a floc rapidly. The free alkali present gives it some softening properties. Unlike aluminum sulphate, it will not convert normal carbonates in bicarbonates. Characteristics of the floc depend greatly upon the condition under which it is formed.



Laboratory Stirring Device

A laboratory stirring device is one of the most needed pieces of equipment in a waterworks laboratory. It is of especial use in coagulation, color, removal, water softening reactions, and taste elimination studies, and for determining minimum quantities of coagulants required for treatment. The paddles usually rotate so as to produce a velocity of 1.5 feet per second.

Lime

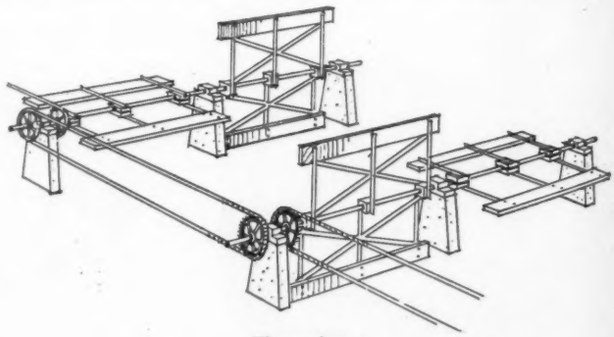
Lime may be used as a coagulant for waters high in magnesium compounds. This is due to the magnesium hydroxide precipitated by excess lime. The floc of magnesium hydroxide has somewhat the same properties as aluminum and iron hydroxides. In softening plants where 20 to 30 parts of excess lime are carried, a saving can be effected by taking advantage of this coagulating material produced in the water.

Other Coagulants

Laboratory experiments have shown aluminum chloride, chromic chloride, and titanium tetrachloride to be good coagulants, but no better than ferric chloride. They are interesting but have no practical use at present.

There is no rule or set of rules for determining the quantity of coagulant required, or which one, or combination of them, is best suited to obtain maximum benefits. A very muddy water in which the turbidity is due to coarse particles will require less coagulant than a less muddy one in which the turbidity is due to fine particles. The presence of organic compounds, or too much or too little acidity or alkalinity (pH value), sometimes prevents coagulation reactions, or causes them to proceed to completion very slowly. Color may prove troublesome by combining with the coagulant to form soluble compounds, making the treated water even more highly colored than the raw water.

The surest way to determine the quantity and type of coagulant required to obtain best results is by laboratory trial tests.



Flocculator

For a dosage in grains per gallon added to one gallon sample, weigh 65 grams of chemical into 1000 ml. of distilled water. Each ml. of this solution added to one gallon of the water to be treated equals a dosage of 1 grain.

For example, to a series of six 1-gallon samples add, respectively 1 ml., 2 ml., 3 ml., 4 ml., 5 ml., and 6 ml. of the coagulant liquid. Stir gently (see laboratory stirring device) for thirty minutes, let settle, then filter portion through a paper filter.* The minimum dose that produces a bright sparkling effluent from the paper filter is the quantity needed.

*From "Water Supply and Treatment," a booklet written by Chas. P. Hoover, and distributed by the National Lime Association, Washington, D. C.

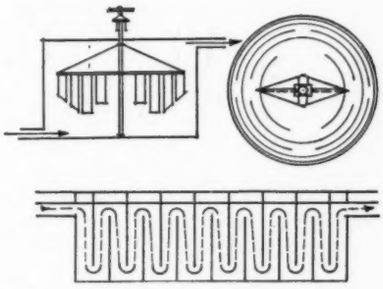
In making comparative tests of different coagulants, a very large number usually must be made. Tests should be made not only on the samples, as are, but also on the samples with acidity or alkalinity (pH value) adjusted to various ranges.

Mixing, Agitation or Fluctuation

After the chemical has been added to the water, the two should be quickly and thoroughly mixed. Prolonged agitation is also desirable and often necessary. In the treatment of turbid water, the precipitate of the coagulation compound should be kept in suspension until it has had sufficient time to collect into clusters a maximum number of the fine particles, which give the water its turbidity. Gentle velocities of from 0.6 of a foot to 1.5 feet per second are adequate. If the water and chemicals are given a quick mix ahead of prolonged gentle agitation, the time is usually only momentary and the process extremely violent. The time of gentle agitation varies depending upon the temperature and the nature of the water treated. From 30 minutes to one hour is the usual practice.

The types of mixing devices used in water purification plants are baffled tanks, with various combinations; tanks provided with rotating paddles or propellers; diffused air supplied from a compressor; and the "flocculator," which is perhaps the latest development.

The flocculator consists of a horizontal shaft, the length of which is at right angles to the flow of water. Paddles attached to this shaft rotate so that an outward travel is given to the upper stratum of water being mixed, and an inward motion to the lower stratum. This inward motion causes the settled floc to be gently swept back along the bottom of the basin, lifted by the upward motion of the paddles and mixed with the incoming treated water. The introduction of already precipitated floc seems to facilitate coagulation.

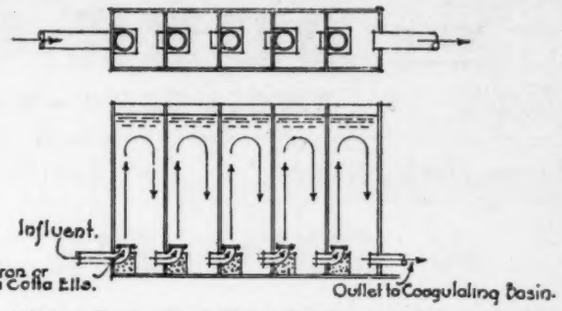


Baffled Mixing Tank, Mechanical Agitator

Views of Mechanical Agitators. Appearance of floc when water admitted in bottom side of tank and taken off at upper side of tank.

Views of four types of agitating devices are here shown. Properly designed baffled tanks are satisfactory, but mechanical tanks are less expensive to build. They remove the necessity of lifting the water the extra two or three feet necessary to pass it through baffled mixing tanks. Although agitators require power to keep them running, the cost of operation, if proper drive is provided, should be less than the cost of the additional lift of the water. They also provide greater accessibility and flexibility.

The paddle area should be at least 25 per cent of the area of the central vertical section of the tank, or 25 per cent of the area of diameter of tank times its height. In the case of large tanks when water is admitted through an inlet at the side or bottom of the tank and discharged at an outlet at the side and top, as is usually done, two distinct zones will develop, an inner and an outer one. The velocity is too low in the inner zone and scarcely any floc can be seen, whereas in the outer zone very satisfactory floc formation is obtained. More uniform velocities are obtained and short circuiting is minimized if the water is discharged through a take-off pipe from the center rather than the side of the tank.



Mixing Tanks Dual Flow Compartment Type

Arrows show path of water through mixer. The upflow is induced by the jet action of orifices in the ells, and the downward flow by gravitation. The general dimensions used are: chamber area in proportions of 18 sq. ft. per million gallons per day, depth equal to a coagulating basin, preferably between 9 and 15 feet. Connecting ells in proportions of one sq. ft. per million gallons per day. Ell discharge ends should not be in excess of 8 ft. below water level. Nipples may be added to bring about these conditions. This scheme is adaptable to square, rectangular or circular basins.

[*Absorbent cotton is just as good, filters much faster, detects effective coagulation more decidedly.—Ed.]

Copper and Health

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.
2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.
3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.
4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.
5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.
6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

Dry Ice as Well Cleaner

Dropping 200 pounds of dry ice down a well casing and thereafter closing the well tight, a well driller has found effective in opening of well screens. As the dry ice "melts," the liberated carbon dioxide gas builds up a pressure which forces the water in reverse of usual flow out through the well screens and surrounding sands or gravel. The pressure is watched on a gage on the well and the relief valve is opened to avoid pressures above 150 lbs.—*Monsanto "Chemical Topics."*

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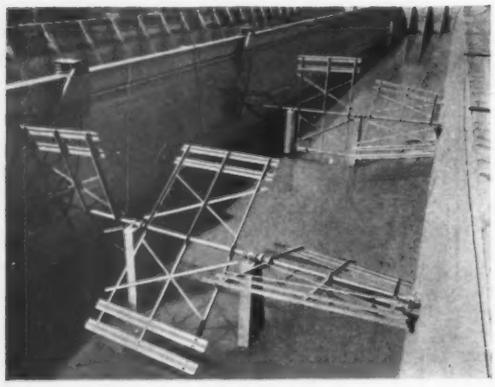
The Dorr Company's function in modern waterworks practice is the pre-treatment of the turbid or hard raw water prior to final treatment. Three Dorr steps—mixing, flocculation and sedimentation—taken in sequence pay for themselves through reduced chemical consumption. The resulting treated water settles and filters more rapidly and yields a final filtered water of definitely improved qualities.

MIXING . . .

First comes mixing, in a Dorrco Flash Mixer. Coagulating or softening chemicals are introduced directly below the throat of a high speed impeller that rapidly and completely diffuses the chemicals throughout the incoming raw water.



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Next comes floc formation in a Dorrco Flocculator. Chemically-dosed water is given a series of gentle "barrel rolls," causing flocs to sweep through the water, impinge on and entrap light suspended particles and finally grow to large dense structures of improved settling and filtering qualities.

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SEDIMENTATION . . .

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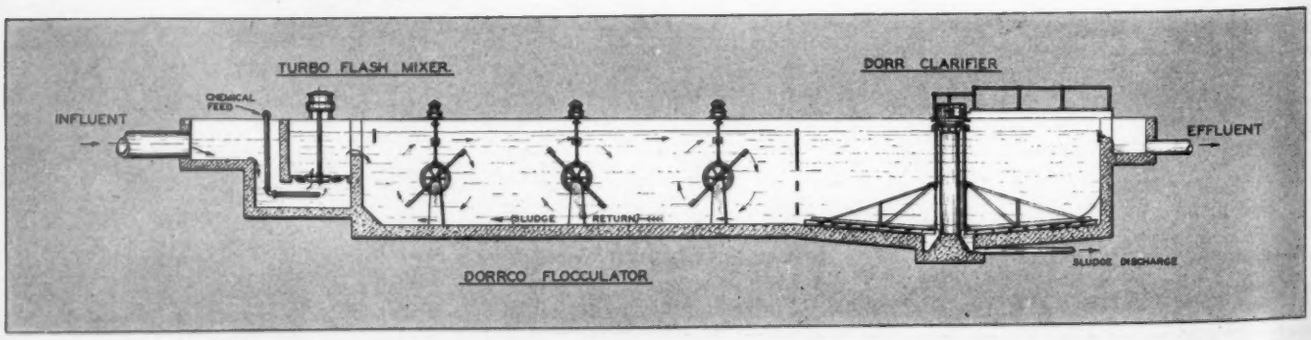
Write for our new bulletins "Flocculation & Mixing" and "Modern Municipal Sanitation."



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PRODUCTS—"Aqua Nuchar," Activated Carbon.

The control of all tastes and odors is now accomplished economically with AQUA NUCHAR powdered activated carbon. The first successful application of activated carbon in powdered form was made by Mr. Geo. R. Spalding of the Hackensack Water Company at New Milford, N. J., in 1928. Since that time the acceptance by water plant operators of this method of combating tastes and odors has been so general that at present over 800 water plants are using AQUA NUCHAR.

Prior to that time, the accepted material for tastes and odors was GRANULAR activated carbon. However, the cost of this type of carbon together with the necessity of installing additional costly equipment, made the general use of GRANULAR activated carbon prohibitive. Therefore, the application of powdered activated carbon to water treatment for taste and odor control may well be classed as one of the greatest advancements in present-day water works practice.

AQUA NUCHAR is a fine black powder having tremendous internal and external surface. It has been estimated that one cubic inch offers a total external and internal surface of 20,000 square yards to serve in adsorption. When activated carbon is placed in water containing impurities, these impurities are attracted to the surface of the carbon, much the same as a magnet attracts iron filings. All of these impurities are retained in the carbon, and subsequently are removed when the carbon is removed by settling or on the filter sand. The action of activated carbon is therefore a physical rather than a chemical one, and an overdose can have no ill effects, such as are encountered with the usual water works chemicals.

Due to its physical characteristics it is possible to feed AQUA NUCHAR by dry feed or solution feed methods or mixed with chemicals. The ideal method of application is by means of a dry feed machine with a water ejector. Solution feed is used in some plants regularly, but the usual practice is to employ this method only temporarily in case of emergency. Since activated carbon is insoluble in water, it tends to settle out, and it is therefore necessary to equip the mixing vessel with an agitator. AQUA NUCHAR has been applied very successfully mixed with chemicals, such as alum, ammonium sulfate, or lime.

NUCHAR is applied at various points prior to filtration depending upon actual operating conditions and particular conditions of the water. The point most commonly used is prior to sedimentation; the carbon being fed in water suspension to the raw water or to the mixing chamber. The application of NUCHAR prior to sedimentation has advantages other than control of tastes and odors. It acts as a nucleus for floc formation, and quite often gives a better and larger floc even with reduced amounts of alum. Many operators report that the black appearance which NUCHAR gives to water aids them in examining their floc and results in closer control. When the NUCHAR passes into the sedimentation basin a large percentage of it settles with the sludge. The presence of NUCHAR in this sludge retards the putrefying action, and prevents fouling of the incoming fresh water. Furthermore, the reduced odor of NUCHAR treated sludge makes it almost a pleasure to clear sedimentation basins.

The other point of application most commonly used is to the settled water in the filter influent line. Plants having very severe taste and odor troubles, or those having only occasional difficulties seem to prefer this point. The adventages are that the NUCHAR is working on a purer quality of water, and quite often less material is required to accomplish the same results. Furthermore, when an occasional difficulty is encountered, applying NUCHAR at the filters saves several hours of complaints. Too much activated carbon fed at this point may decrease the runs on the filters. If it is necessary to feed 30 lbs. per M. G. or more it is advisable to split the treatment or go back to a point in the sedimentation basin.

The foregoing refers to plants equipped with filters. It is also practical to apply activated carbon in powdered form where filtration is not practical. The NUCHAR is first stirred up thoroughly in water, and then fed, preferably by means of a spray, to the surface of the water. In the case of large reservoirs the NUCHAR suspension has been fed from a boat equipped with an outboard motor. The suspension was allowed to run in just in front of the propeller, and in this way was scattered fairly uniformly. It is suggested that the NUCHAR be fed in proportions of 5 lbs. per M. G. for the entire amount of water in the reservoir. If the tastes and odors are not sufficiently reduced, repeat the treatment with the same dose a week or two later. After the NUCHAR has been applied it is necessary to keep the reservoir out of service until the fine particles have had an opportunity to settle. It is advisable to allow two days for settling, although a satisfactory water can usually be delivered in a much shorter time. We have been advised of one distributing reservoir being treated one evening with a proportion of 30 lbs. per M. G., and never taken out of service. Although the tap water was examined closely, no signs of carbon were noticeable. Due to the fact that there was practically no draw on this reservoir during the night, the actual settling time was only about ten hours.

AQUA NUCHAR has successfully controlled tastes and odors which have been characterized as:

Earthy	Fishy
Woody	Marshy
Vegetable	Swampy
Bitter	Muddy
Aromatic	Chlorine

which may originate from decaying vegetation; Algae, such as synura, synedra, asterionella, cyclotello, etc. Industrial Trade Wastes, such as phenols, solvent naphtha, volatile oils. Decomposing Sludge.

Realizing that taste and odor troubles come suddenly in water plants, we have spotted stocks of AQUA NUCHAR at strategic points throughout the country in storage warehouses. You can feel assured that your order will receive immediate attention and you will be very agreeably surprised at the prompt service we can give you.

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Zeolite water softeners are coming into wide-spread use for softening municipal water supplies, for which purpose they offer a number of distinct advantages. Prominent among these are their simplicity; flexibility, ease of operation; positiveness of results; ability to operate on either a gravity or pressure system; low installation and operating costs; no sludge disposal problems.

As a zeolite water softening plant may consist of one or more units, a plant, when installed, need not be larger than is needed for present requirements. Additional units may later be added as needed.

Municipal zeolite water softening plants may be operated so as to secure effluents of any desired degree of hardness. They may also be employed with iron or mangenese bearing well waters. They remove iron or manganese the same way as they remove hardness, and at the same time.

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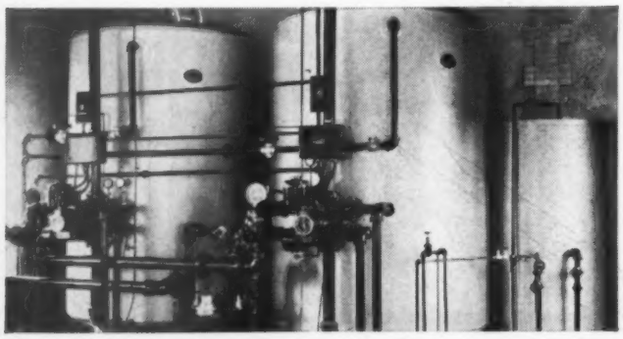
By a system of electrical controls, completely automatic operation of a zeolite water softening plant is secured. These controls may be applied to either a gravity or pressure type of plant and may also be applied to existing installations.



Municipal Automatic Zeolite Water Softening Plant at Elmore, Ohio

The automatic zeolite water softeners have proven especially popular in municipal water softening plants and the great majority of the newer municipal plants are of the completely automatic type. Write for details.

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All types of zeolites, including ZEO-DUR, the standard greensand base zeolite; SUPER-ZEO-DUR, the high capacity greensand base zeolite; DECALSO, the high capacity manufactured zeolite; and MANGANESE PERMUTIT for iron and manganese removal.

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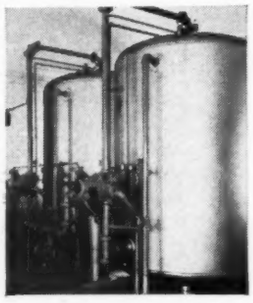

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Control Unit of Electro-Chemical Feed — double drum type for feeding two chemicals—adjusted separately and instantly by the finger tip.

All types of chemical feeds, constant or proportionating, for feeding sulphate of alumina or other coagulants; soda ash; lime; silicate of soda, etc. These include the following types: gravity; pressure solution; dry; and electro-chemical.

The electro-chemical feed, illustrated above, is particularly applicable where accuracy of feeding is essential in addition to which it is of a simple and rugged construction.

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The above list represents but a few of our bulletins on special subjects, any of which may be obtained free on request. Kindly order by name.

CONTROL OF ALGAE*

By FRANK E. HALE, Ph.D.

Dept. of Water Supply, New York City

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4.5H_2O$) Per 100 lbs. solution.	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys may *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500.	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

*This material has been taken from the very useful booklet—"The Use of Copper Sulphate in Control of Microscopic Organisms"—(1935 revision) published for free distribution by Nichols Copper Co., New York City.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡ — Aromatic, geranium, fishy	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Cyclotella†‡ — Faintly aromatic			1.0
Diatoma† — Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion — Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡ — Earthy	0.36*-0.50*	3.0-4.2	1.0
Stephanodiscus	0.33	2.8	
Tabellaria‡ — Aromatic, geranium, fishy	0.12*-0.50*	1.0-4.2	0.5*-1.0
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡ — Grassy, nasturtium, fishy			0.5*-1.0
Draparnaldia	0.33	2.8	
Eudorina — Faintly fishy	10.00	83.0	
Entomophora	0.50	4.2	
Glœocystis — Offensive			
Hydrodictyon† — Very offensive	0.10	0.08	
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina — Faintly fishy	10.00	83.0	
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡ — Fishy	0.25	2.1	0.3*-1.0
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡ — Moldy, grassy, vile	0.12*	1.0	0.5*-1.0
Aphanizomenon‡ — Moldy, grassy, vile	0.12-0.50*	1.0–4.2	0.5*-1.0*
Clathrocystis — Sweet grassy, vile	0.12*-0.25*	1.0-2.1	0.5*-1.0
Cœlosphærium‡ — Sweet grassy	0.20*-0.33	1.7-2.8	0.5*-1.0
Cylindrospermum — Grassy	0.12	1.0	
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia — Moldy, grassy			
Protozoa:			
Bursaria — Irish moss, salt marsh, fishy			
Ceratium†‡ — Fishy, vile, (rusty brown color)	0.33	2.8	0.3*-1.0
Chlamydomonas	0.50–1.0	4.2-8.3	
Cryptomonas — Candied violets	0.50	4.2	
Dinobryon‡ — Aromatic, violets, fishy	0.18*	1.5	0.3*-1.0
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium — Fishy	0.50*	4.2	
Mallomonas — Aromatic, violets, fishy	0.50	4.2	
Peridinium — Fishy, like clam-shells	0.50*-2.00	4.2-16.6	
Synura‡ — Cucumber, muskmelon, fishy, bitter taste	0.12*-0.25	1.0-2.1	0.3*-1.0
Uroglena‡ — Fishy, oily, cod-liver oil taste	0.05*-0.20*	0.4-1.6	0.3*-1.0
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa† — Very offensive decayed	5.00	41.5	
Cladothrix	0.20	1.7	
Crenothrix†‡ — Very offensive decayed, medicinal with chlorine	0.33 -0.5*	2.8-4.2	0.5*
Leptothrix†			
Sphaerotilis, natans† — Very offensive decayed	0.40	3.3	
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 –0.50	0.8-4.2	
Nitella flexilis† — Objectionable	0.10 -0.18*	0.8-1.5	
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

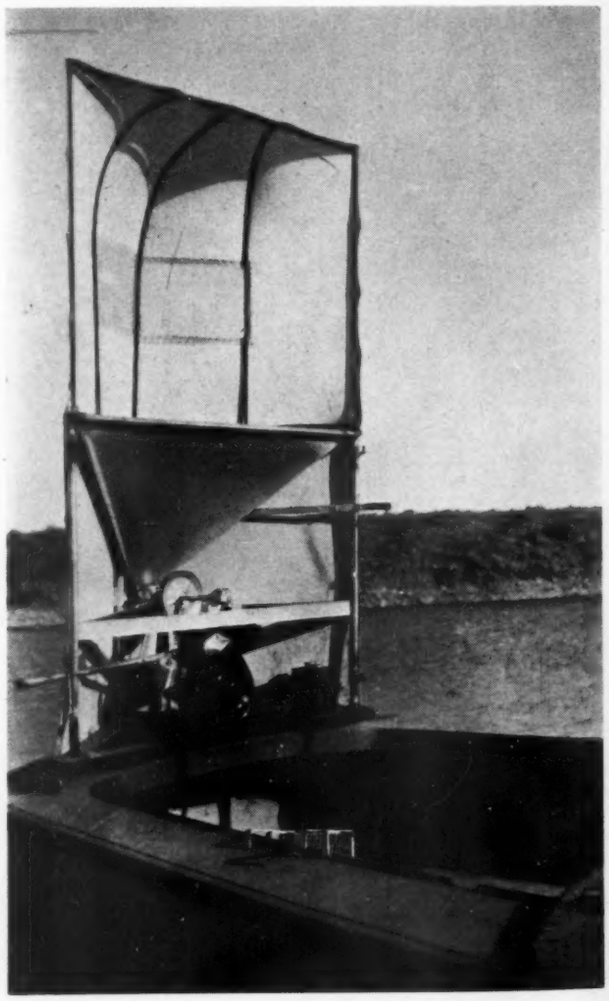
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



Copper Dusting Equipment in Boat Stern—Used on Los Angeles reserves for broadcasting pulverized copper sulphate and around harrd-to-reach shores

A METHOD OF APPLYING COPPER SULPHATE

By PAUL SMITH*

Baltimore, Md.

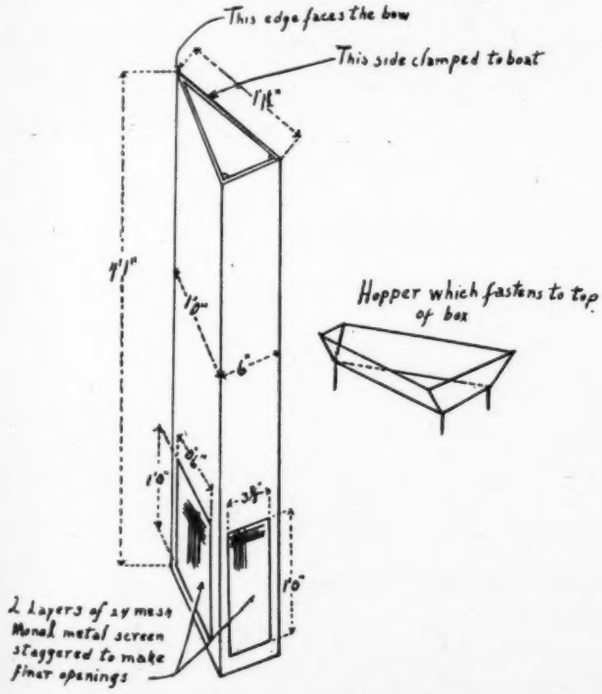
In the summer of 1930 it was decided to treat Back River, which is a tributary of Chesapeake Bay, with copper sulphate for the purpose of checking algae growths.

A few preliminary tests were made to determine the most advantageous method of applying this chemical. We found the bag-digging method unsatisfactory and developed the following device and scheme.

A wooden box was built for holding the copper sulphate. This box, as the sketch shows, is about 4 ft. long, and has a triangular cross-section with a small hopper at the top to facilitate the dumping of chemicals into the box. Near the bottom of the box are two openings, covered with two layers of twenty-four mesh monel metal screen, staggered to make finer openings. The side adjacent to the boat has no openings, and was fastened to the boat with clamps. The larger opening faced forward and the smaller opening the rear. In comparison with the use of bags, the box offered very little resistance in the water, so that the boat could be run at a constant speed.

The capacity of the box including the hopper was 100 lb. The first time the box was used it vibrated, and had a tendency to work loose, but by securing the bottom to the bow of the boat with a rope, as illustrated, this difficulty was overcome.

It was found that 50 lbs. of large crystals could be dissolved in 10 minutes, but with small crystals the time was reduced to 6½ minutes. In order to dissolve all the sulphate and at the same time cover the desired area, the rate at which the sulphate dissolved was controlled by altering the exposed screen area with adjustable wooden covers, placed over the screens. As the boat proceeded, a swirling motion of the water entering through the



Sketch of Copper Sulphate Solution Box (Slide Gate to Control Rate of Solution Not Shown. See Photograph of the Box)

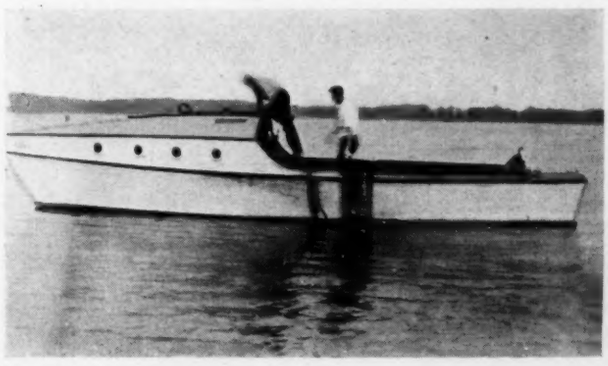
screened opening was set up in the lower part of the box, but the upper part remained dry. An accumulation of lint from the bags, which contained the sulphate, and dirt from the river water partially blocked the screens, and the adjustable covers had to be removed at intervals. To overcome this disadvantage a wooden sliding device (gate) was provided to cover the front screen.

In practice, 50 lbs. of sulphate were placed into the box, and a mark made on the box at the top of the crystals. Another 50-lb. portion was then immediately added, and the time for the above mentioned mark to be seen was observed. In this manner the sulphate was added, 50 lbs. at a time. The slide at the bottom of the box was adjusted, depending upon the time necessary for the boat to cover the area to be dosed. If the interval necessary to dissolve 50 lbs. increased, the area of the screen at the bottom of the box was enlarged by raising the adjustable slide. As the screens became clogged, this slide was raised, so that the

Side View of the Solution Box (Solution Control Gate in Wide Open Position)

time for the 50 lbs. to dissolve was kept fairly constant. If the screens became quite clogged they were brushed just before the next trip, the dry accumulation being readily removed in this manner. On one occasion a blow torch was used to burn off the accumulation of material on the wires.

By use of this box 1,250 lbs. of copper sulphate were distributed evenly over an area of 1.2 sq. mi. in less than four hours and with less than half the labor required when, previously, burlap sacks had been used.



Solution Box in Place on Boat

*Assistant Chemist, Bureau Sewers.

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

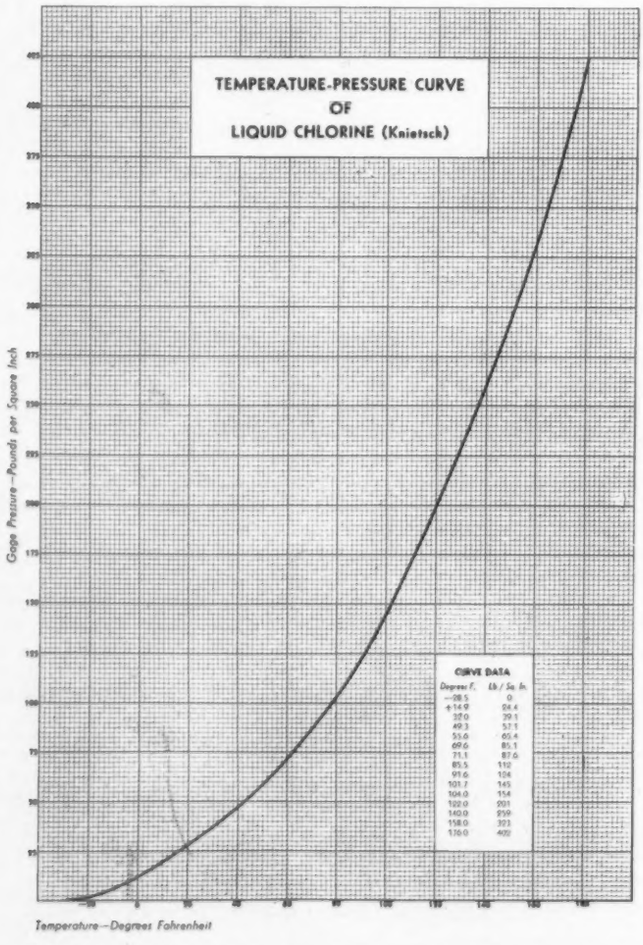


Fig. 1—Relation between Temperature and Vapor Pressure

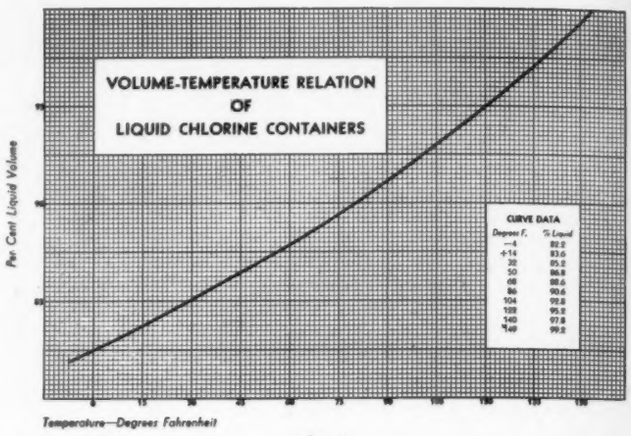


Fig. 3

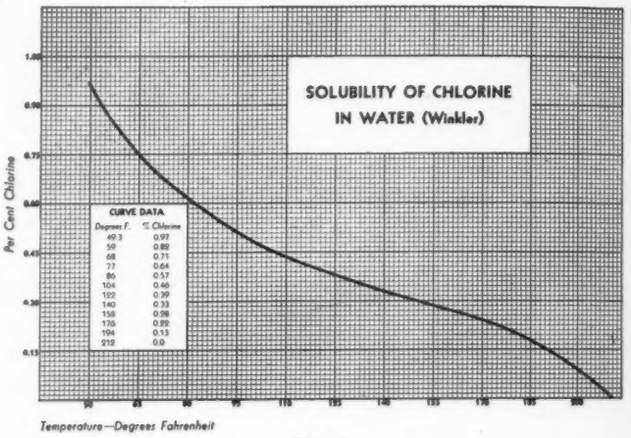


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.

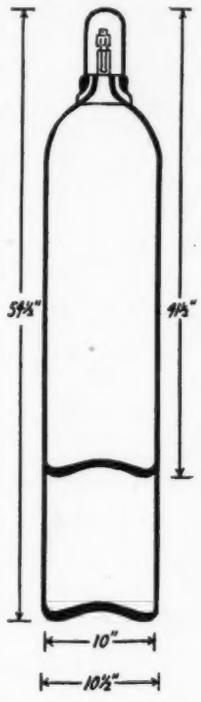
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.

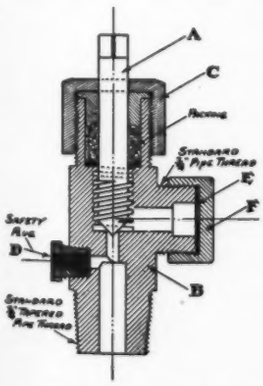


Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par. 431B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

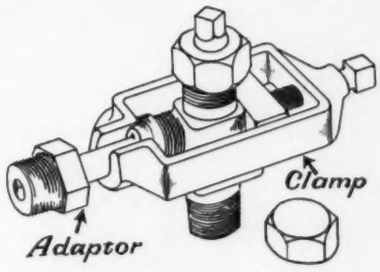


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

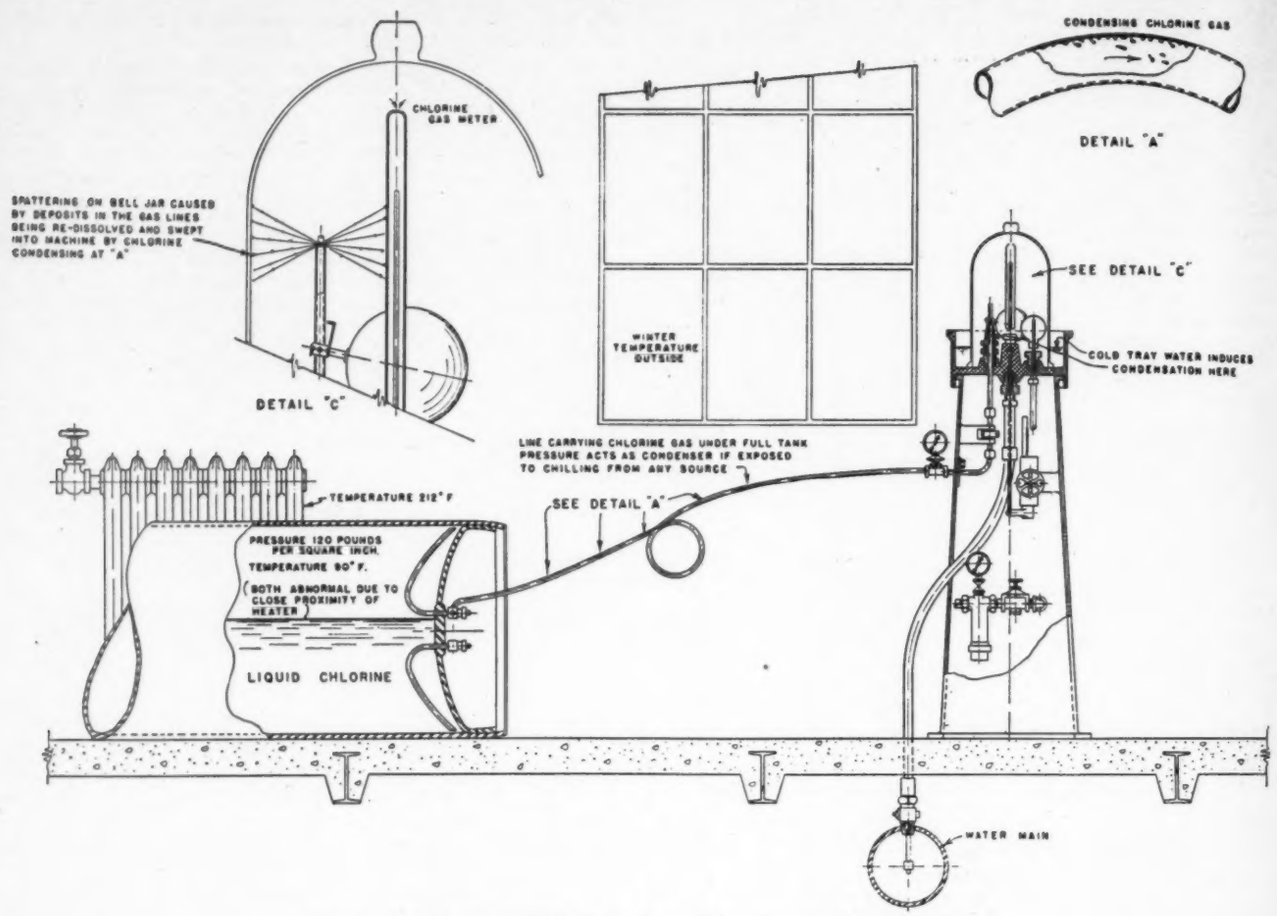

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH
TEMPERATURE 80° F.
BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Handling Chlorine Leaks

(The safety information in the following paragraphs has been taken largely from Sale Practices Pamphlet No. 71 of the National Safety Council, as recommended for revision by The Chlorine Institute in December, 1935. For more complete safety information write the National Safety Council, 20 North Wacker Drive, Chicago, Illinois.)

The ventilation provided for the chlorine room, mechanical or otherwise, should be of such nature as to remove and dissipate the gas with the least injury to persons and property.

Stand leaking container upright if possible. This will prevent the escape of liquid chlorine and under these conditions vaporization diminishes rapidly as natural chilling takes place and the escape of chlorine into the air will then be very slow. Ton containers have two valves, and in case of a leaky valve, the container should be rolled so the valves are in vertical plane with the leaky valve upward. In this position the valve will leak chlorine gas, not liquid chlorine.

In case of accident indoors, every effort should be made to remove the leaky container outside the building. *Water played on a gas tank will not stop the leak.* Water in large quantities played on a cylinder gas leak will assist in diluting and dissipating the gas. Water played on a liquid leak may provide

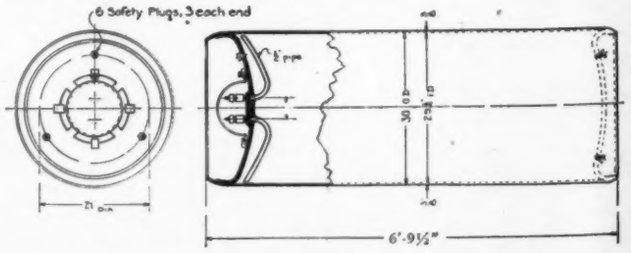


Fig. 12—Cross Section of a Ton Container

chlorine hydrate from which the evaporation of gas is slow. These operations should only be undertaken by a competent person wearing an approved gas mask in good order. When a pond or large body of water is nearby, the leaking container should be submerged in the water. Loose earth, cement, lime (both slaked and unslaked), and heavy textiles (both wet and dry), such as bagging and felt, will act as an absorbent or blanket.

It is illegal to ship a defective or leaking chlorine container. If there is an accident, telephone the car owner or nearest chlorine plant for assistance. The telephone numbers and residence addresses of the nearest chlorine plant organization members should be posted in the office of the person in charge of the handling of chlorine in the plant of the user, and in the office of the manager.

Gas Masks

It is imperative that some form of protection be provided for emergencies. Several types of gas masks approved by the U. S. Bureau of Mines and suitable for high concentrations of chlorine are available. For this purpose, a sufficient number of suitable gas masks should be on hand and located at a readily accessible point outside the area likely to be affected in case of accident. The instructions accompanying a mask concerning its care and use should be obeyed implicitly. Everyone who is in danger of being accidentally exposed to high concentrations of chlorine should be provided with a gas mask, preferably to be used by no one else. He should be familiar with the instructions accompanying it and trained to hold his breath and to put the mask on quickly and properly. Periodic strict inspection and maintenance of approved gas masks are essential.

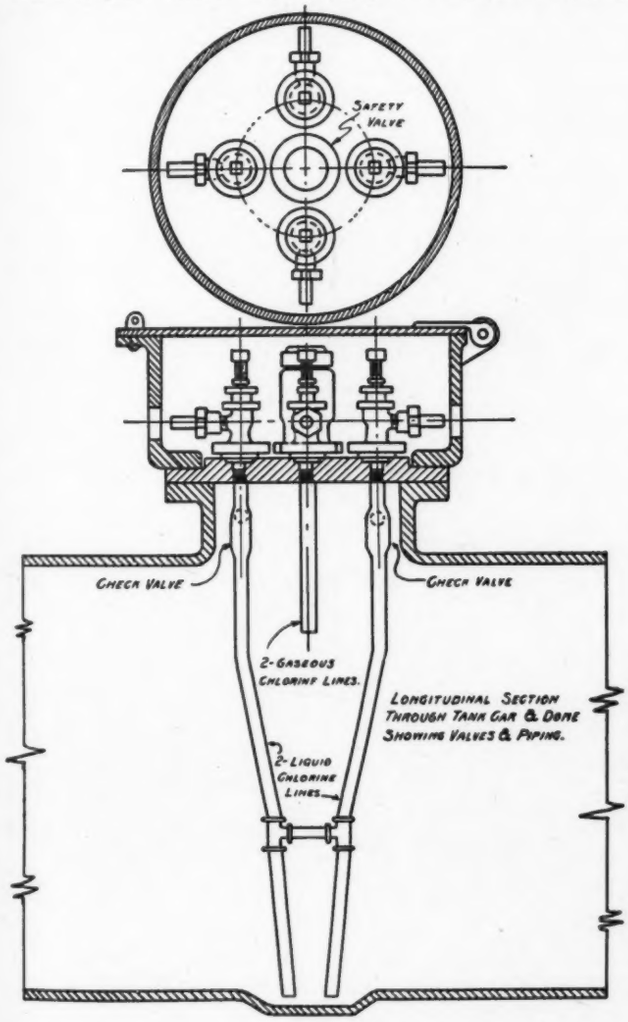
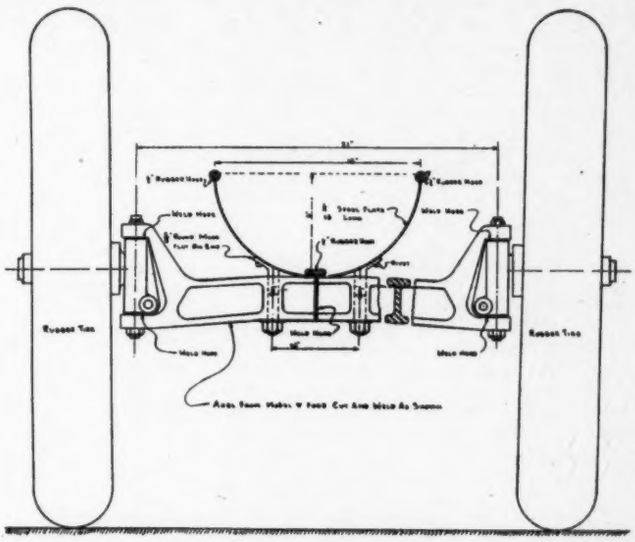


Fig. 17—Details of Dome and Inner Shell of Single Unit Chlorine Tank Car

Safety Cylinder Handling Carriage

The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.



Model "T" Cylinder Carriage
Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.

In Position

Ready to Ride

SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*

Richmond, Va.

There appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable or explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory materials to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

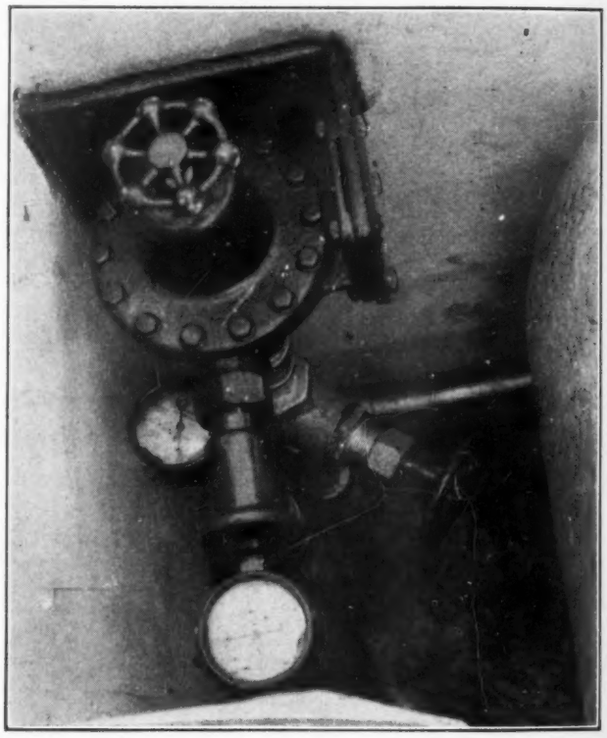
Soft copper tubing connections (cadmium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (re-liquifaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It

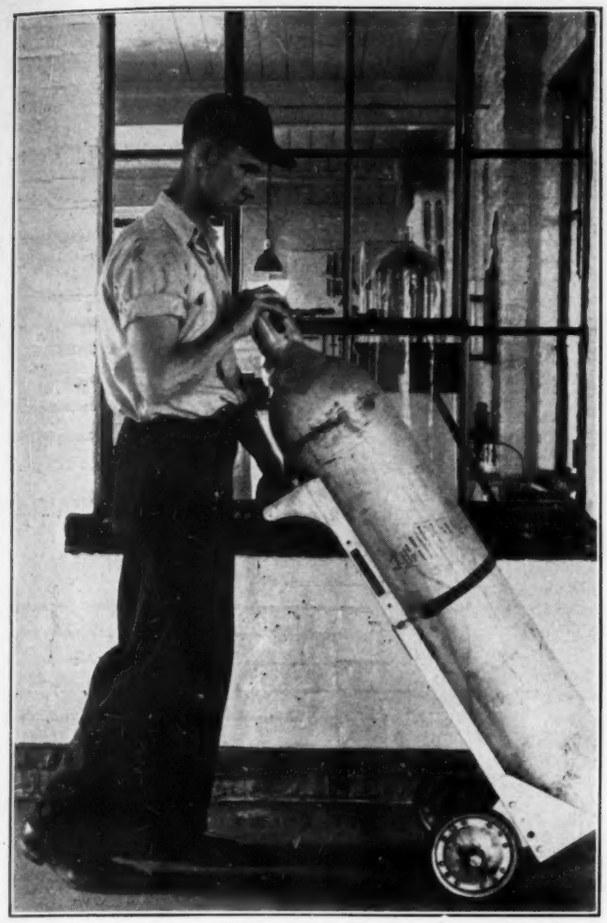


One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-tetrachloride are the only safe chlorine equipment cleansers to employ.

Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid in the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va.



Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overloaded cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed container. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in use only a few 150 pound cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining

The Chlorine Leak Tester

air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct, are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Water played on a gas leak will not stop the leak, but in large quantities will assist in diluting and dissipating the gas. However, water played in a liquid leak will provide chlorine hydrate, from which hydrate the evaporation is slow. Such operations should be undertaken only by a competent person wearing an approved gas mask and such protective clothing as rubber gloves (loose fitting) and a rubber apron.

There is so much difference of opinion (See A.W.W.A. Committee Report, Jour. A.W.W.A., Sept., 1935) as to the best medical treatment to be given those suffering from exposure to chlorine; and the "Do's and Dont's" are almost as numerous; that the writer rafrains from expressing any opinion for anyone else's use on this subject at this time.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

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The Long Range Set is a portable outfit. The Dalite Set is recommended where all determinations are to be made in one place or where standard lighting conditions are desired during both day and night. For water work each of these sets contains a Chlorphenol Red Slide Comparator complete, two extra color standard slides, Bromthymol Blue and Phenol Red, vials of indicator solution, pipettes and 5cc test tubes. Complete range pH 5.2-8.4 in intervals of 0.2 pH. Long Range Slide Comparator, $40.00. Dalite Slide Comparator $48.50. Extra color standard slides $7.50 each.

The Enslow Slide Chlorimeter, for chlorine control is supplied separately ($17.50) or in combination with either the Long Range Set ($51.50) or Dalite Set ($60.00). All prices F.O.B. Baltimore.

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DETERMINATION OF RESIDUAL CHLORINE*

No reagent is at present available which is specific for chlorine. The most frequently used indicators in water or sewage which has been treated with chlorine or hypochlorites are orthotolidine or starch iodide, both of which measure other oxidizing agents as well as chlorine. Ferric and organic iron compounds, manganese compounds, algae, etc., are examples of substances which may produce color similar to chlorine, or affect the intensity of color produced by chlorine. This interference generally is of such nature that it superimposes an added similar color upon the color produced by chlorine. *If proper precautions are not taken in the tests outlined below, free chlorine may be recorded when none exists.* The technician must satisfy himself as to the presence and quantity of interfering substances present in the sample to be tested.

Orthotolidine Method—A

For chlorinated waters with less than 0.01 p.p.m. manganese; for 0.01 p.p.m. nitrite; or for 0.3 p.p.m. ferric iron.

Orthotolidine Solution. Dissolve 1 g. orthotolidine (m. p. 129° C.) to a total volume of 1000 ml. by grinding the orthotolidine to a thin paste with 5 ml. of 1:5 HCl in a six-inch mortar and then adding 150 to 200 ml. of distilled water. Solution is immediate. The strong solution is washed with distilled water into a 1000 ml. graduate and brought with distilled water to a total volume of 505 ml., after which 495 ml. of 1:5 HCl are added, making the total volume 1000 ml.

Permanent Standards. These are prepared with copper sulphate solution (1.5 g. $CuSO_4 \cdot 5H_2O$ dissolved in 1 ml. concentrated H_2SO_4 and diluted to 100 ml. with distilled H_2O) and $K_2Cr_2O_7$ dissolved in 1 ml. concentrated H_2SO_4 and diluted to 1000 ml. with distilled H_2O. When using these standards, color comparisons should be made in 100 ml. Nessler tubes having the graduation mark 300 mm. from the bottom. A tolerance of ±10 mm. is permissible but not desirable. It is best to use matched tubes.

The standards are made by mixing in a tube the quantities of reagents indicated in the table below and then diluting to the 100 ml. mark with distilled water. The tubes should be protected from dust and evaporation by sealing micro-cover glasses on the top with collodion, Canada balsam, or similar material.

Chlorine Parts per Million	Solution of Copper Sulphate Milliliters	Solution of Potassium Dichromate Milliliters
0.01	0.0	0.8
0.02	0.0	2.1
0.03	0.0	3.2
0.04	0.0	4.3
0.05	0.4	5.5
0.06	0.8	6.6
0.07	1.2	7.5
0.08	1.5	8.2
0.09	1.7	9.0
0.10	1.8	10.0
0.20	1.9	20.0
0.25	1.9	25.0
0.30	1.9	30.0
0.35	1.9	34.0
0.40	2.0	38.0
0.50	2.0	45.0
0.60	2.0	51.0
0.70	2.0	58.0
0.80	2.0	63.0
0.90	2.0	67.0
1.00	2.0	72.0

These standards should neither be stored nor used in direct sunlight and should be renewed at least each six months. Excellent glass and liquid standards are commercially available but should be used only after checking for accuracy against the above standards.

*From a bulletin on "Liquid Chlorine"—Prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.

Procedure:

The sample should be at least 20° C. and elevation of its temperature is permissible when accomplished by rotating it in an Erlenmeyer flask held in boiling water. The temperature at no time must exceed 40° C.

Place 100 ml. of the sample in a 300 mm.-100 ml. Nessler tube and mix with it 1 ml. orthotolidine solution. Place in the dark and allow the color to develop for not less than 5 and not more than 15 minutes. Compare with the standards. If the color develops to a blue or green tint—as may be the case with strongly alkaline waters—the orthotolidine solution described under "B" may be used eliminate this tint interference.

Comparisons are best made in cabinets wherein "daylight" electric light is properly diffused, or in north daylight against a white background. *Comparisons should not be made in sunlight.*

Orthotolidine Method—B

For use where interference is experienced with oxidizing substances other than chlorine and where nitrite is less than 0.3 p.p.m.

Special Orthotolidine Solution. Add to 100 ml. orthotolidine solution prepared under "A," 100 ml. distilled H_2O and 60 ml. concentrated HCl.

Magnesium Sulphate Solution. Dissolve 20 g. $MgSO_4 \cdot 7H_2O$ in 100 ml. distilled H_2O.

4.5 N Sodium Hydroxide. Dissolve 19 g. NaOH in 100 ml. distilled H_2O. Titrate and adjust to 4.5 N. The chlorine demand if any must be satisfied.

Procedure:

To 200 ml. of the sample add 2 ml. $MgSO_4$ and 2 ml. 4.5 N NaOH. Mix thoroughly and separate precipitate by centrifuging at 1000 r.p.m. or more for three minutes. Decant 100 ml. of the supernatant into a 300 mm.-100 ml. Nessler tube. Proceed as under "A," except that 3 ml. of the special orthotolidine are used in this test.

Starch Iodide Method

For use where nitrite is more than 0.3 p.p.m., or as an alternate where manganese is interfering.

Potassium Iodide Solution, Alcoholic. Dissolve 75 g. chemically pure KI (free from iodine or iodates) in a small amount of freshly boiled and cooled distilled H_2O. Add 100 ml. ethyl alcohol and make up to 1 l. with freshly boiled and cooled distilled H_2O.

0.01 N Sodium Thiosulphate. Dissolve 2.483 g. chemically pure $Na_2S_2O_3 \cdot 5H_2O$ in 1 l. freshly boiled and cooled distilled H_2O. Standardize against 0.01 N. $K_2Cr_2O_7$. Check at least once each month. 1 ml. is equivalent to 0.354 mg. chlorine.

Starch Solution. To 1.25 g. potato starch add a little cold H_2O to make a paste. To this add 250 ml. and boil for ten minutes. After cooling add 0.313 g. salicylic acid as a preservative. This reagent deteriorates on standing. If a pinkish tint is noted at the end-point a new starch solution should be prepared.

Procedure:

The accuracy of this determination increases as the temperature is lowered. If the sample has a temperature above 20° C., it should be chilled at least to that point. Additional cooling in ice water, or if desired in an ice-salt mixture, to 1° C., will further increase the sensitivity of the determination. Place 1000 ml. of the sample in a white porcelain casserole. Add from a pipette with the tip below the water surface 10 ml. KI solution and stir gently. Allow to stand 5 minutes. Add 5 ml. starch solution. Discharge the blue color by adding $Na_2S_2O_3 \cdot 5H_2O$ from a burette. The amount of $Na_2S_2O_3 \cdot 5H_2O$ in ml. times 0.3546 equals chlorine present in mg., or as the determination is outlined, in p.p.m.

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Our liquid chlorine is produced with c.p. standards of purity. Customers are quick to testify to the quality of our product, the cleanliness of cylinders, the workability of our valves, and the promptness of our service. Shipments are made in 10, 15, 25, 100, and 150 pound cylinders; multiple unit tank cars of 15 one-ton containers; and single unit tank cars holding 16 and 30 tons.

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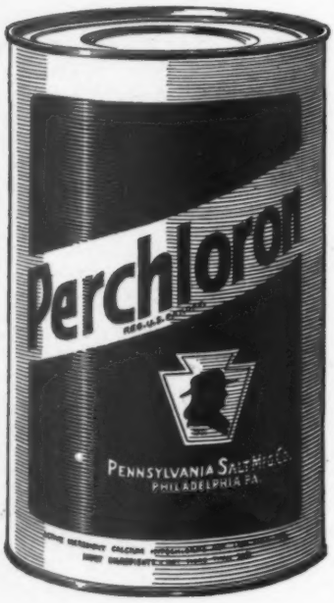

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Every liquid chlorine consumer will find it most convenient to have one of these products on hand for sterilizing new mains, tanks, and reservoirs; for controlling algae growth; and for cleaning filter sand.

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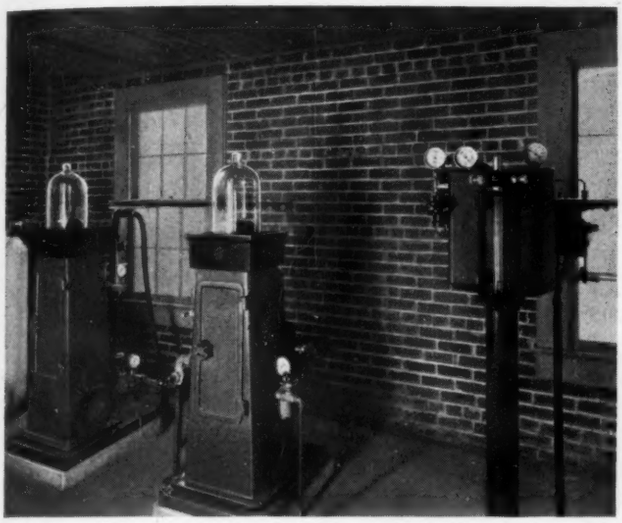

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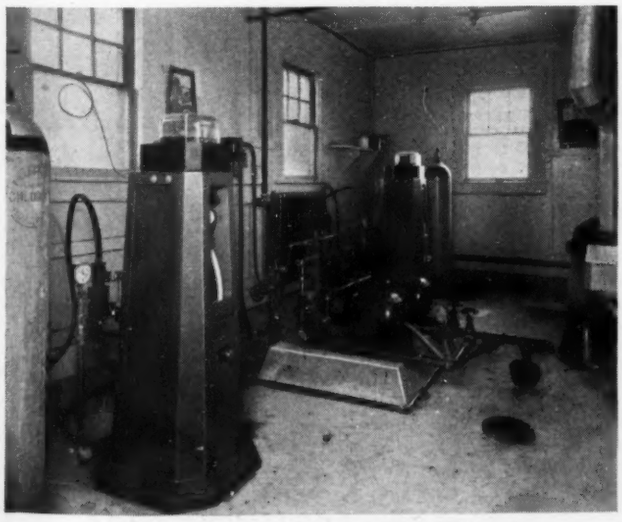

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The ammonia-chlorine process of water treatment has passed beyond the experimental stage and is accepted as a definite and valued aid in water works operation. Chloramine—formed by the combination of chlorine and ammonia—while somewhat slower in bactericidal action than chlorine, offers many distinct advantages. Chloramine residuals persist over long periods and are tasteless and odorless. Chlorophenol and certain organic tastes and odors are prevented.

Chlorinous tastes are eliminated, this being of particular advantage on small gravity water supplies with widely fluctuating flows and with a chlorinator operating at a fixed rate at considerable distance from the town. Aftergrowths in the distribution system are destroyed and algae control made far more efficient owing to the persistent residual being carried through basins, filters and reservoirs. Finally, and most important, a new factor of safety is added by maintaining sterilizing action throughout the distribution system to the consumer's tap, thus eliminating all dangers of subsequent pollution.

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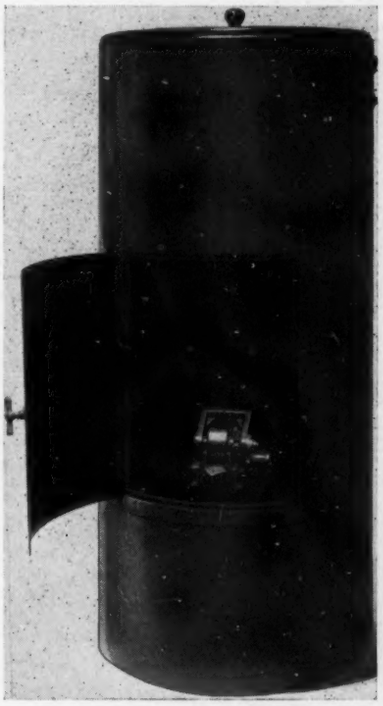
The development of dry chemical application has been of great value in both sanitary and industrial fields. Difficulties from leaking tanks, corroded constant level boxes, clogged orifices, broken valves, and all the untidiness and disagreeable features incident to solution feed systems are eliminated. Of particular advantage in filter plants for applying alum, lime, soda ash or carbon, dry chemical application effects large savings in labor and materials.



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AIR CONDITIONING IN RELATION TO WATER CONSUMPTION

By LOGAN L. LEWIS*

Newark, N. J.

While it may be true that air conditioning has but recently become of peculiar but important interest to water works authorities, it is by no means a novelty. The industry is some thirty years old. During the first twenty years of its life, application was limited almost entirely to industrial plants and, hence, few people knew of it. About ten years ago its application began to spread rapidly to theaters, department stores, restaurants and other buildings in which the public gather. This second phase of development brought improvements in equipment, made price reductions possible, and greatly broadened the market.

From an air conditioning point of view, every human being in Jones' store is a heater, giving off heat in both its sensible and latent form, or, with freedom of description, as dry and moist heat. Every light, every electrical device, every coffee urn is a heater. The rays of the sun heat the building structure where they strike it, and heat also flows in through it, because a lower temperature is maintained inside the structure. Therefore his system must remove heat and moisture when the weather is warm and add heat and moisture when the weather is cold.

For effectively removing heat, we must have a refrigerating machine of which there are many types, all of which must be provided with means for removing the effluent heat. This effluent heat usually is carried away wholly or partly by the water furnished, and requirements may be great. In winter requirements for water are minute. Thus, demand for water is a seasonal one and proportional to the quantity of heat which must be removed.

A simple way to get rid of this heat is to buy water from the water utility and pass it through his condenser to the sewer. If this were the only way to do it, water departments might well be concerned by the demand. But, in certain cities, the cost of water was high and the manufacturers of air conditioning and refrigerating equipment sought means of reducing water costs. And, so, economic forces began to stimulate the development of equipment which would reduce sales resistance by reducing the need for water where the rates were high, or where the threat of water shortage might restrict its use. This has borne fruit, so that there is available water conserving equipment which may, in some localities, reduce sales that water works managers would like to make. However, in other localities this improvement may prove a desideratum in reducing excessive demands.

The Economy of the Cooling Tower

The first stage of this development was the cooling tower—that slatted structure which you will recognize as the architectural abortion you have seen upon the roof of some local ice plant. This cooling tower is a means of heat disposal. The water passing through it is recirculated, being pumped through the condenser where it receives heat, and then through the cooling spray tower where it gives off this heat to the air. Some of the water is carried away by the wind, some of it is lost by evaporation, and that which is lost must be replenished from the source of water supply. This loss is quite small, so that the use of this cooling tower for heat disposal has cut the demand for water to less than 10 per cent of what it would otherwise be.

To be fair to the cooling tower, it must be said that much has been done to improve its appearance. The second stage was the development of the evaporative condenser, in which the functions of the condenser and the cooling tower have been combined. The features of water conservation have also been further improved thereby and the space occupied by equipment greatly reduced. This piece of equipment may be placed upon the roof of a building and appear as a small rectangle, or, if it is feasible to lead air to and from it through ducts, it may be tucked away in one corner of the machinery room.

Since there is no windage loss from the evaporative condenser, it requires less than 5 per cent of the water which you would otherwise furnish. Both the tower and the evaporative condenser are instruments for the conservation of water and are fully developed practically and commercially.

*Chief Engineer, Carrier Corpn., Newark, N. J.

Water Demands of Modern Equipment

What is the magnitude of this demand for water going to be and what will be its characteristics? Let us examine the demands for water of the several types of prevalent installations of air conditioning, which are given in Table I which accompanies this discussion.

B.t.u., or thermal units, per person will vary somewhat for each installation, but limits of variation are well known. Hours of operation per season can readily be set for maintenance of the desired conditions. Load factors, or the relation of average load to maximum load, are based on experience. Gallons of both maximum and average demand must be based on an average water temperature and an average balance between water and power. Hence, Table I is necessarily composed of figures which are admittedly controversial as to the interpretation of experience, for multifarious economic forces press in some localities for excessive use of water and in others for conservation thereof.

For a given electric power rate, cold water may throw the balance in favor of heat disposal entirely by water—warm water may do the opposite. Low power rates may favor conservation of water—high power rates, the opposite. A combination of high's of water temperature and power cost operate strongly in favor of heat disposal by evaporation.

The complexity of these economic forces becomes apparent when it is realized that power for air conditioning may cost from less than 1 cent per k.w.h. to more than 3 cents; that water may be purchased at rates varying from 45 cents per 1,000 cu. ft. up to $2.85—perhaps higher; that the temperature of the water coming from mains may range in summer from 56 to 85 degrees F.; and that pocketbook limitations to available capital may enforce the purchase of equipment which, being of low capacity, is above average in demand for water or power, or both.

But, let's continue our examination of the averages arrived at in Table I as they are carried forward in Table II. Three important facts become obvious.

First, that the demand for water is seasonal. It is high in summer and, as previously stated, insignificant in winter. An 120-day cooling season is typical of New York. In the South, it may exceed 150 days.

Second, that economic forces and restrictive regulations, such as are now applied in New York, did, in 1935, lead to extensive purchase of evaporative heat disposal systems. As a result, water consumption was cut by 60 per cent.

Third, that within the cooling season, the peak demand is far above average consumption.

Two figures in Table II are of such importance that they

TABLE I

DEMANDS OF SEVERAL TYPES OF AIR CONDITIONING INSTALLATIONS FOR WATER

VALUES ARE PER PERSON
SEASON OF 120 DAYS
WATER COOLED CONDENSERS

	BTU/HR.	MAX. DEMAND GAL./HR.	HRS. OPERATION PER SEASON	GAL./SEASON AT MAX. DEMAND RATE	LOAD FACTOR PERCENT	PROBABLE USE GAL./SEASON
RESIDENCE	4,000	40	2,900	160,000	30	48,000
TRAIN	1,400	14	1,200	16,800	50	8,400
OFFICE	4,700	47	1,200	56,400	40	22,500
LUNCH ROOM	1,600	16	900	14,400	50	7,200
RESTAURANT	2,000	20	1,200	24,000	60	14,500
DRUG STORE	2,000	20	1,800	36,000	60	21,500
THEATRE	1,000	10	1,500	15,000	30	4,500
DEP'T. STORE	1,600	16	1,200	19,200	60	11,500
AVERAGE	2,300			42,500		17,200

TABLE II

AIR CONDITIONING REQUIREMENTS FOR WATER

GAL./PERSON

THE FOLLOWING ARE "COLD AVERAGES", ADMITTEDLY CONTROVERSIAL AS TO THE INTERPRETATION OF EXPERIENCE.

	NO EVAPORATIVE CONDENSERS OR COOLING TOWERS USED.		BASED ON USE OF EVAPORATIVE CONDENSERS OR COOLING TOWERS ON 60% OF INSTALLATIONS. 1935 EXPERIENCE	
	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE
PER SEASON OF 120 DAYS	42,500	17,200	17,000	7,000
PER DAY FOR SEASON OF 120 DAYS	350	140	(140)	60
PER DAY FOR YEAR 365 DAYS	120	50	50	(20)

have been encircled. Note carefully that they are *not* the *per capita* consumption that water works men are accustomed to using.

Air-conditioning-wise, they will become per capita consumption if and when air conditioning installed and operated for the entire population served by the water system. This does not mean that every building in a city must be completely conditioned. It does mean that the sum total of the number of people upon which the capacity guarantees of the systems are based has reached the sum total of population. In still other words, it means that there will exist an air conditioned spot for each and every person in a city, and no more.

If air conditioning sales double every four years, at some time in a period between 1945 and 1950 the per capita demand upon water systems for modern air conditioning may become:

(1) Maximum rate—35 gallons per day per capita.

(2) Average rate—5 gallons per day per capita.

Provided the present practice of using evaporative condensers and cooling towers is maintained. But if evaporative condensers and cooling towers be used exclusively from now on and be substituted for existing condensers, now wasting water, then these two rates would be cut to:

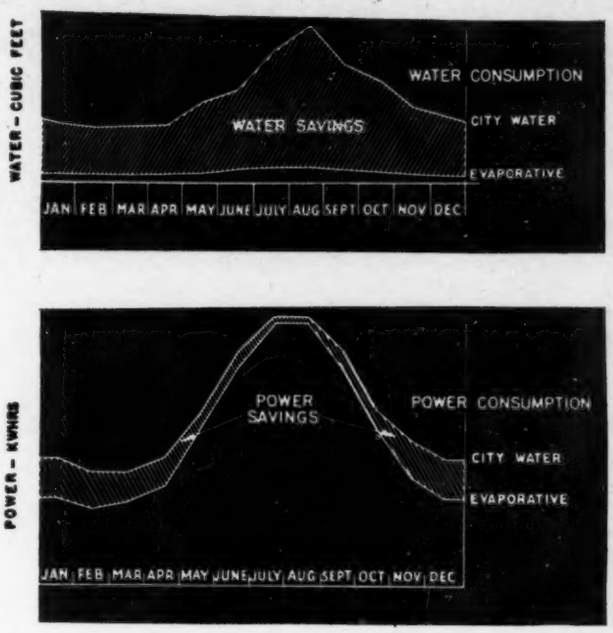
(1-a) Maximum rate—23 gallons per day per capita.

(2-a) Average rate—3 gallons per day per capita.

Water works managers may be divided into two groups:

1. Those to whom air conditioning offers an opportunity to sell more of their product.

2. Those to whom any increased demand will present a serious problem, and those who may now be unable to meet existing demands if rainfall is below average.



Water Conservation Made Possible by Use of Modern Evaporation Condensers

My conclusions are:

(a) With respect to Group 1: The maximum demand of 23 to 35 gallons per capita per day may overtax existing water works pumping equpiment or, if not that, the capacity of the mains at certain focal points.

(b) With respect to Group 2: Their inability to assure a continuity of supply, either at present rates of consumption, or at present rates plus 3 to 5 gallons per capita per year average, or to pump and distribute as in (a), should be faced squarely as the facts stand, and proper restrictive measures instituted.

(c) Generally: That the number and complexity of factors are such that the problem will not yield except to analysis of a specific survey.

(d) That it is to our common interest to know and face the facts; and, worth our mutual effort to obtain them.

Terminology in Pumping*

Static Head

Static Head is the vertical distance in feet beeween the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

WATER WASTE SURVEYS

By A. D. STALKER*

Ottawa, Canada

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered. The person who has to pay for water through a meter can generally be depended upon to be economical in its use. To make the watertaker pay for the water he wastes, will reduce that waste to a minimum.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

In Ottawa when defects in plumbing fixtures are located by any one of the inspectors, the owner of the property is given 48 hours in which to make the necessary repairs. The inspector re-examines the premises at the expiration of the 48 hours, and if repairs have not been made, the service is shut off, and before it is again turned on repairs must be effected, and the owner is compelled to pay the sum of $1.00 as a charge for the services of the turnkey.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly down-stream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the up-stream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe coefficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

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How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

It is necessary that those entrusted with waste reduction should become thoroughly acquainted with the conditions that exist in the various districts. The population and how it is distributed, and whether the area is industrial or residential, must be known in order to determine what quantity of water would be sufficient for its needs.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and

the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent. The following is offered as an illustration: Some years ago, this city had a serious epidemic of typhoid fever. Water from any source other than the city mains was in great demand. During this time the writer noticed people drawing water from what appeared to be a spring located at the bottom of a hill. Those familiar with the locality insisted that this spring had always been there, and the city had had a sewer installed to carry off the overflow from it. A sample of the water was analyzed and the analysis showing that the water was very similar to that supplied by the city, the area in the vicinity of the spring was examined. At the top of the hill a 2-in. service that had been installed some thirty-odd years previously, was found to be running full bore. This was stopped and the "spring" immediately dried up.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible. In most cases a test of the electrical conductivity of a sample of the water is sufficient to decide. If the result of this test is not conclusive, an analysis of the water is made, and if it shows that the water comes from the mains, the leak is located by one of the methods mentioned above.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication. To know where to send the men requires an intimate knowledge of sub-surface conditions throughout the city. Pipes crossing waterways and mains in rocky sections through which large sewer or other excavations have been cut, should be sounded, and if the leak still remains unlocated, short readings of the flow to districts is resorted to.

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
·· *but* ··
Don't Ignore Leaks!
* * *
Satisfied customers are worth more to us than revenue secured from water *uselessly* passing through meters.
INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

MAINTENANCE OF VALVES AND HYDRANTS

By CARL A. HECHMER*

Hyattsville, Md.

It is surprising, especially in small towns and villages, how little attention is given the maintenance of gate valves and fire hydrants on their water systems. The need of good engineering advice and design is recognized and is compulsory in almost every state. Practically every state health department has a law compelling the submission of plans for approval before a water system can be built. The question of good materials is also generally given the utmost consideration and the best valves and hydrants obtainable, in the judgment of those in charge, are purchased and put into the water system. In many instances they are promptly forgotten until an emergency arises and quick, sure operation is necessary. Unless valves and hydrants are given regular attention and properly maintained. the water works superintendent has no assurance that they will function properly. This fact applies to any make of valve or hydrant or to any other mechanical device or piece of machinery. Unfairly, the failure reflects on the designing engineer or the manufacturer of the material, and the local department is given a clean bill of health.

Valves

All valves on a water distribution system should be inspected once each year. This is the minimum requirement of the Fire Underwriters' Association. However, semi-annual inspection is advisable, if finances will allow it. Not only will the mechanical condition of the valve be assured, but valve boxes covered by paving material or earth will be located and reset ready for immediate operation in emergency. This is especially true in rural and suburban sections with a large percentage of unpaved streets. When a large leak occurs, excitement prevails and considerable time may be lost in locating a valve box. Occasionally a large stone or stones are found down in valve boxes and these conditions are revealed on inspection and removed. In case the valve has to be dug up, uncovering the valve, it is advisable to install new packing in the packing gland, which will prevent digging it up for repacking for a long time. Always repack a valve when it is uncovered for any repairs. Packing is cheap and easily installed while the valve is exposed. To dig up a valve just to stop a packing leak is an expensive operation. Inspection also locates valves which were carelessly or accidentally left closed. Any water distribution system is weakened by gate valves being closed when they should be open.

How a Valve Inspection Should Be Made

In addition to the box inspection, a valve inspection should proceed as follows: First set the valve key on the valve nut preparatory to turning the stem. Pour a small quantity of kerosene or diluted automobile crankcase drainings down the valve key stem. The oil will run down the key to the operating nut, thence to the valve stem and lubricate the valve stem against the packing gland. Finding its way into the packing gland, the packing will be softened and revived. Then operate the valve up and down several times, bringing the gate down into the groove hard each time and then opening the valve about one-quarter way. Valve troubles, preventing complete shutdown, are usually caused by the accumulation of sediment under the seat. Each time the gate is pushed down into the groove a small portion of this sediment is pushed out the sides. The high velocity of the water through the partly opened valve removes what is pushed out and the operation is repeated until the groove is sufficiently cleaned to allow the gate to seat properly. This procedure is especially recommended when valves fail to hold when attempting a shutdown. Of course, if the groove is filled with large stones or jointing material, the valve must be dug up and taken apart for repairs. The writer once operated a 16-inch valve up and down thirty times and secured a perfectly tight shutdown. The valve had not been operated for a long time. having been declared worn out, since it always allowed a large volume of water to pass with the gate turned down hard with levers on the key.

In operating the valve a check should be made of the number of turns on the stem. Generally, for the same size and make of valve, the number of turns to close or open the valve completely is the same, and a check can be made to see if the stem is bent, preventing the valve from completely closing or opening. Either condition should be corrected, as partly open valves weaken the system and, obviously, partly closed valves will not shut off the water.

If the valve stem can be turned around and around with no apparent effect on the gate, the stem is broken and must be repaired.

Geared valves, usually set in manholes, must be given special attention on inspection. The gears should be cleaned with a wire brush and greased with a light clinging grease. The stuffing box should, of course, be examined, and the by-pass valve should receive the same attention as the smaller valves on the distribution system.

Fire Hydrants

Proper care in the installation of a fire hydrant is necessary and makes maintenance less expensive. Proper drainage of the hydrant barrel after the main valve is closed is essential to prevent freezing of the hydrant in northern climates. The best method is to provide a bed of crushed stone or gravel around the bottom of the hydrant. The amount of stone necessary is dependent on the nature of the soil. In loose sandy soils a much smaller drainage bed can be provided than in a clay soil that absorbs water very slowly. A safe margin is to provide sufficient area to allow the drainage of an amount of water equal to twice the contents of the hydrant barrel. Connections are often made direct from the hydrant drain valve to the sewer. However, there are two serious objections, first, the cost and, second the direct connection between a sewerage system and a domestic water supply, even though the possibility of contamination reaching the water in the mains is remote. Generally water mains are laid on one side of the street and sewers on the other. Hydrants are installed at the curb on the same side as the water mains to shorten the length of the lead. To connect each hydrant drain across the street to the sewer would prove much more expensive than providing a stone drainage bed.

Fire hydrants must be inspected at least twice each year, in the spring and fall. Four inspections annually should be made, if possible, and this number of inspections is advocated by the Fire Underwriters' Association. In high value districts, weekly inspections are often made during extremely cold weather. Arrangements should be made between the water department, the fire department and any other possible users of hydrants to report to the water department immediately after using a hydrant during freezing weather and an immediate inspection made to insure the good condition of the hydrant. Use of hydrants by private individuals or contractors should be allowed only by special permit, and the daily charge made high enough to permit daily inspection during freezing weather. During mild weather the inspection charge can be reduced, as weekly inspections are sufficient.

Valuable data may be secured by the fire hydrant inspection by measuring the static pressure, the residual pressure with one nozzle open, and the flow of water from the hydrant. [See artitcle on making hydrant flow tests (Wilson) elsewhere in this issue.—Ed.] Weak points on the distribution system can thus be determined and improvements due to new installation readily noted. System weakness due to unknown closed valves is also discovered and can be corrected.

Procedure for Making a Hydrant Inspection

The following procedure is suggested for making a hydrant inspection:

First make a physical examination of the hydrant, noting the condition of the operating nut, the nozzle caps and chains, and the general appearance of the hydrant. Then listen for leakage with an aquaphone placed on the operating nut. Then with the nozzle caps on tight open the hydrant valve. If static pressure readings are to be taken, replace one of the nozzle caps with one connected to a pressure gauge. Note if all the nozzles are tight in the hydrant and whether the drain valve has closed properly. If the drain valve has not closed water will appear around the barrel of the hydrant on the outside. Then close the main hydrant valve and take off one of the nozzle caps. Observe the rate of drainage of the barrel to determine whether any obstruc-

*Engineer of Distribution, Washington Sanitary District.

tion has entered the drain valve. To clean the drain valve replace the nozzle cap and crack the main valve. As it requires about three full turns open on the main valve to completely close the drain valve on most makes of fire hydrants, the latter is still open on two turns. The full pressure of the water in the hydrant generally will push out any obstruction in the drain hole and the jet effect of the water through the hole will cut away the stone or earth which has packed around the outside. This simple remedy will eliminate the necessity of digging up the hydrant, in most cases, to correct drainage troubles.

With one nozzle cap off, open the hydrant and thoroughly flush out the water in the lead. At this time the observation of residual pressure and rate of flow should be made. Then close down the hydrant slowly. If the hydrant fails to close off entirely, the trouble is probably being caused by an obstruction under the main valve. Do not put extra leverage on the hydrant wrench, but open the hydrant up again and then close it, repeating the operation several times. Do not attempt to close down beyond the point where the obstruction prevents the main valve from seating properly, as the obstruction will become embedded in the main valve and connot be flushed off, or the valve seat will be damaged. Both valve and valve seat are damaged by attempts to force closing against obstructions. Foreign matter can generally be dislodged by flushing and it is then not necessary to dismantle the hydrant.

After the hydrant is closed and the rate of drainage checked, the stem should be oiled and the nozzles greased with a graphite grease. This kind of grease will not wash off and it prevents the nozzle caps from sticking.

Inspection Records

Record of the inspection should be kept on a field sheet. The location of the hydrants to be inspected can be entered on the sheet in the office. These will allow correct routing and prevent skipping any hydrants. The information on the field inspection sheets can then be transferred to a permanent record card in the office. A card should be in the file for each hydrant, stating the size, make of hydrant, and information regarding pressure at the hydrant. The date of each inspection should be entered on the card together with the observed pressures and rate of flow. Necessary repairs and their costs can also be recorded on the card and a history of each individual hydrant is easily obtained.

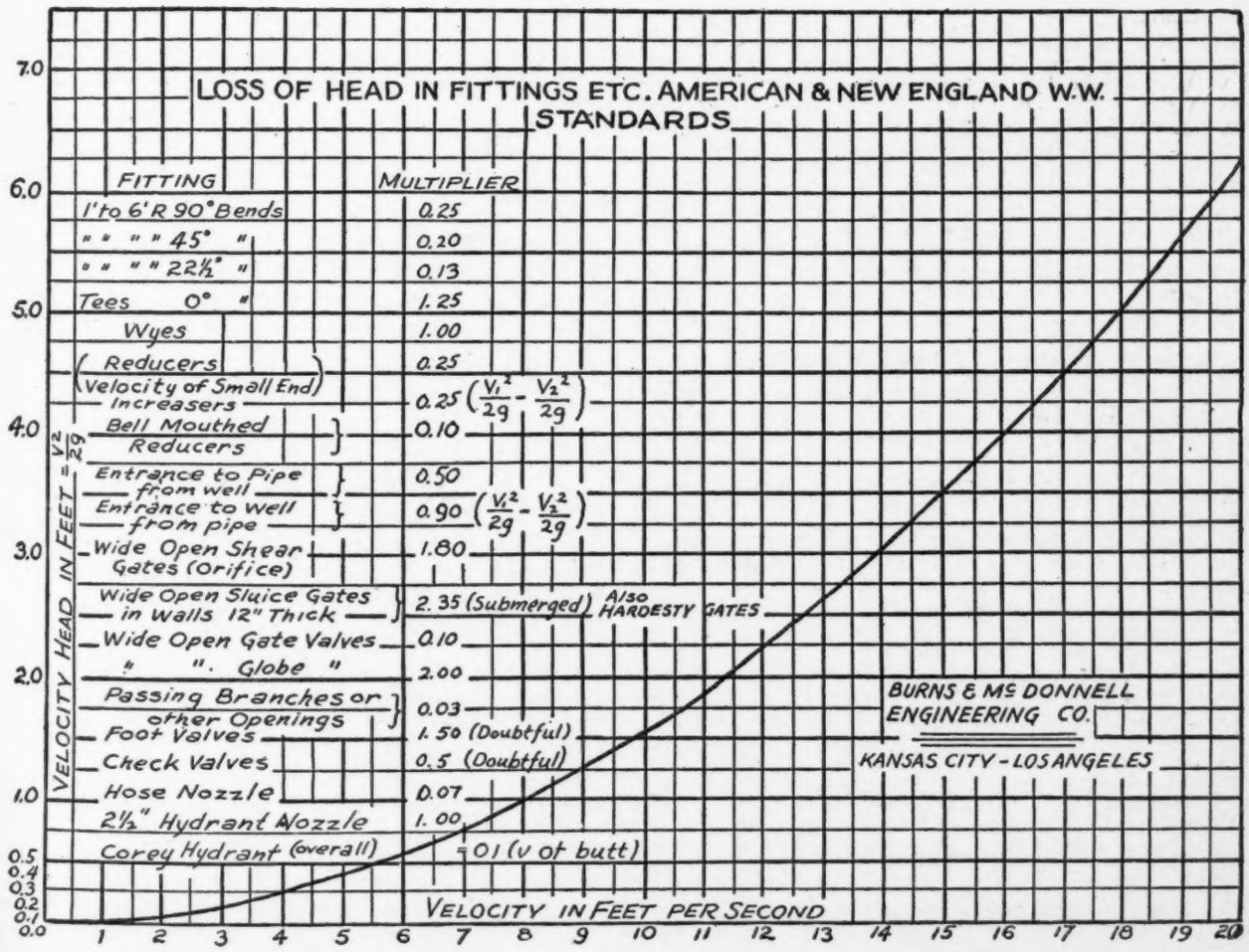
For quick reference the following is suggested: Use a map of the water system mounted on wall board with a push pin to denote the location of each hydrant. The color of the pin can show the condition of the hydrant as reported daily by the hydrant inspectors and the repair foreman. Use a blue pin for a hydrant in good condition, a black pin for a hydrant in need of minor repairs but not out of service, and a red pin for a hydrant out of service. Then when an inspector reports a hydrant out of service it is possible to tell at a glance whether the hydrants around it are in good condition. If several makes of hydrants are in use, it is an advantage to know the make of hydrant before sending out a repair gang so the proper parts can be carried along. By using a small round colored disc under each push pin it is possible to determine at a glance the make of each hydrant, a different color being used for each make of hydrant.

Loss of Head Through Valves and Fittings

(*Burns and McDonnell*)

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)


LOSS OF HEAD IN FITTINGS ETC. AMERICAN & NEW ENGLAND W.W. STANDARDS
FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " " 45° " 0.20
" " " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
(Velocity of Small End) Increasers 0.25 (V1²/2g − V2²/2g)
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe 0.90 (V1²/2g − V2²/2g)
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged) Also HARDESTY GATES
Wide Open Gate Valves 0.10
" " Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) 0.1 (v of butt)
VELOCITY HEAD IN FEET = V²/2g
VELOCITY IN FEET PER SECOND
BURNS & McDONNELL ENGINEERING CO.
KANSAS CITY - LOS ANGELES

HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON

Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

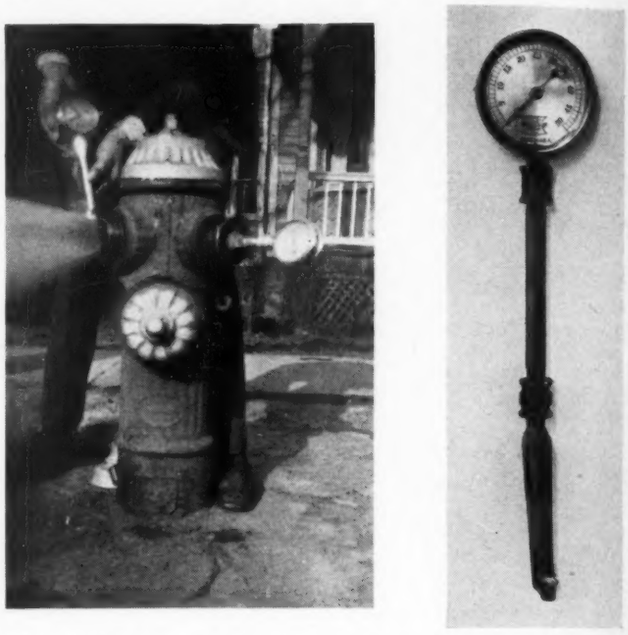
There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Hydrant Discharge

Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings) Hydrant Pitot Tube with Gage at Right

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained the diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

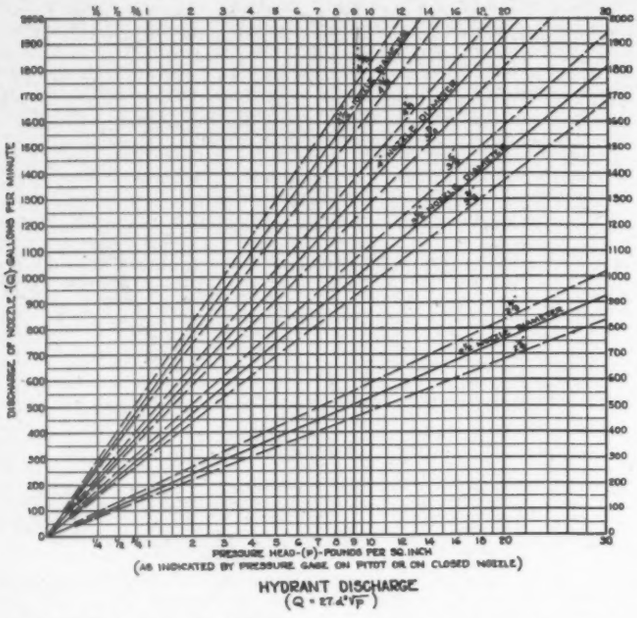
From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

TABLE 1—HYDRANT DISCHARGE*
Gallons per minute = $27 d^2 \sqrt{p}$
Gage Reading—Hoze nozzle diameter in inches [d]

p	2 1/16	2 3/16	2 7/16	2½	2 9/16	2 5/8
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE-(Q)-GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d² √P)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280 \text{ gal. per min.}$$

which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association,* Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

Inclined Diagonal Pipe Runs—Calculating Pipe Lengths

By CHARLES FRICK

Darby, Pa.

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\theta) \qquad \text{Formula III}$$

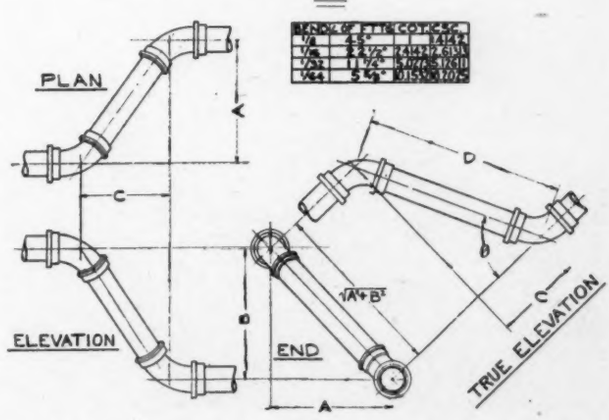
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64 = 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

EXPERIENCES IN WATER MAIN CLEANING

By CHARLES STREITHOF

Genl. Supt., Dept. of Water Works, Evansville, Ind.

Before the Indiana Section of the American Water Works Association, I had the pleasure of presenting a paper entitled, "Inserting Gate Valves Under Pressure." (See WATER WORKS AND SEWERAGE—June, 1934.)

After the valve inserting job was completed, having seen the condition of our important mains, I felt justified in asking for an appropriation, to start cleaning some of the mains. I was able to convince our Board of Water Works Trustees of the necessity for, and the importance of, this work. It was decided to at least clean some of the larger and older mains; and, a contract was made with the National Water Main Cleaning Company of New York City, to do the cleaning.

The cleaning was started on six thousand (6,000) feet of 16-inch pipe and was continued until the contract was completed. Under the contract a total of 37,956 feet of 12, 16 and 20-inch mains were cleaned, and practically restored to their original carrying capacities. The results obtained were so gratifying and satisfactory that the Water Works Trustees were thoroughly convinced of the advisability of continuing this excellent work. A second contract was made with the same company to clean all mains of 10 to 30-inch diameters which had been laid prior to filtration. The total length of mains cleaned under the second contract was approximately 87,500 feet, and the results obtained were as good as, if not better than, those of the first contract. The Board of Trustees then decided that it would be wise to clean all pipes laid prior to filtration, and a third contract was made with the same company, to cover approximately 450,000 ft., which included principally 6 and 8-inch pipe.

Cleaning Procedure

The preparations and cleaning operations are simple, yet most effective. The section of line to be cleaned is "killed" by closing two valves, one nearest the inlet, for the entrance of the cleaning apparatus, and the other nearest the outlet. At the inlet end, the pipe is exposed and a piece of the main, about 6 ft. long, is removed and cleaned by hand. The cleaning device (sometimes called the "rabbit") is placed in it, and the section is then returned permanently to the line by employing a sleeve or coupling and using the bell end of the existing pipe. At the outlet the line is also exposed, where a smaller piece is removed, depending on the diameter, so as to permit a 45-degree bend of the same size to be attached to the end of the line to be cleaned. This joint is made with yarn only. And to the 45-degree bend is added a short piece of pipe, jointed with yarn also, to bring the line up to, and a little above, the level of the street. Then the valves controlling the lines leading off from the one to be cleaned are closed. Likewise all curbcocks are closed. It is now time to start the cleaning apparatus on its journey. The valve nearest the inlet is opened. The water entering the dead line hits the cleaning machine and as the pressure and volume increase, the machine starts to move, and if there is no obstruction in the line, such as a partly closed valve or large pieces of lead

An Increasing Interest Is Shown in Cleaning Water Mains. This Job Was at Evansville, Ind.

Ample Evidence That Evansville's Mains Needed Cleaning

from a poorly poured joint, the machine will travel the entire length of the line to be cleaned and come out on to the pavement at the 45-degree outlet. The rate of travel is never alike in any two pipe lines of the same size and length. In cleaning 8,257 ft. of 30 in. pipe the cleaning machine traveled at a speed of 60 ft. per minute and discharged 47 truck loads of mud, not counting that which went into the sewers.

While the machine is moving, enough water passes it to serve as wash water, which helps to reduce the pressure of the material ahead of the machine, and long before the appearance of the machine, some of the obstructing material will be seen on the pavement. Almost from the moment that machine starts to move from the inlet end, until it is out of the main, the wash water which precedes it is very dirty. Immediately following the appearance of the machine at the outlet the water practically clears up, but it is advisable to permit the water to run a short time to thoroughly flush the line. When the machine has done its job, and the line has been flushed, it is a simple task to remove the makeup at the outlet, replace the piece of pipe there, open the valves which had "killed" the line and then those controlling the side lines, and finally the curbcocks.

Result of Cleaning

The results from main cleaning at Evansville were most gratifying. Velocity tests were run on various lines before cleaning, and the drop in pressure noted, as well as the discharge at the hydrants. The same hydrants were used after the mains were cleaned, and when the readings were taken, the difference showed an increase of 15 to 35 per cent in the water discharged. With two hydrants discharging 1,000 gallons per minute each, a drop of but two to four pounds was noted, whereas before cleaning a drop of six to fifteen pounds was common.*

In addition, practically all the valves in the pipe lines were operated and tested, and those found defective were repaired or replaced. The customary annual inspection of valves is not necessary on the lines which have been cleaned, because of the very thorough job done in conjunction with the cleaning program.

Under the three contracts 506,129 ft. of pipe were cleaned as follows:

Diam.	Feet	Diam.	Feet	Diam.	Feet
30-in.	10,725	24-in.	2,196	20-in.	13,563
16-in.	30,238	12-in.	43,007	10-in.	4,609
8-in.	65,206	6-in.	324,350	4-in.	12,236

The cost was:

Contract cost	$55,700.52
Labor furnished by water department	27,881.22
Material furnished by water department	10,329.30
Repairing paved streets	5,330.41
Total cost	$99,241.45

[*Recently a 48-inch intake main 2000 ft. long under 30 ft. of water was successfully cleaned of 8 tons of tuberculated material at Erie, Pa., to raise the coefficient from C = 57 to C = 87 and yield of 23 m.g.d. raised to 35 m.g.d. It represented a new experience in main cleaning.—Ed.]

The average cost was 19.6 cents per foot of pipe (all sizes) cleaned.

Average material cost was 3 cents per 100 ft., which included paving, pipe, lead and yarn, repairing old valves and new valves where necessary.

During the pipe cleaning, the question was often asked: "How did all the mud get in the pipes?" The answer is this: The first water works was built in 1873 and took the supply direct from the Ohio River and pumped it into the pipe system without any settling or filtering.

In 1912 when the present filter plant was placed in operation, every effort was made to flush the mud out of the pipe lines but without success. On account of lack of funds the pipe cleaning job was delayed.

The question has been asked: "How did you pay for the pipe cleaning job?" The answer is this: The Water Department has always made a nice profit but in order that our books will show no loss when making such a large expenditure at one time, a "Deferred Charge" scheme has been instituted in order to spread the costs over a period of 10 years. However, understand, the Water Department payed all of the bill in cash—the "Deferred Charge" being only a matter of bookkeeping to spread the cost out.

WATER SERVED AT WELL-WATER TEMPERATURE

By WM. M. RAPP

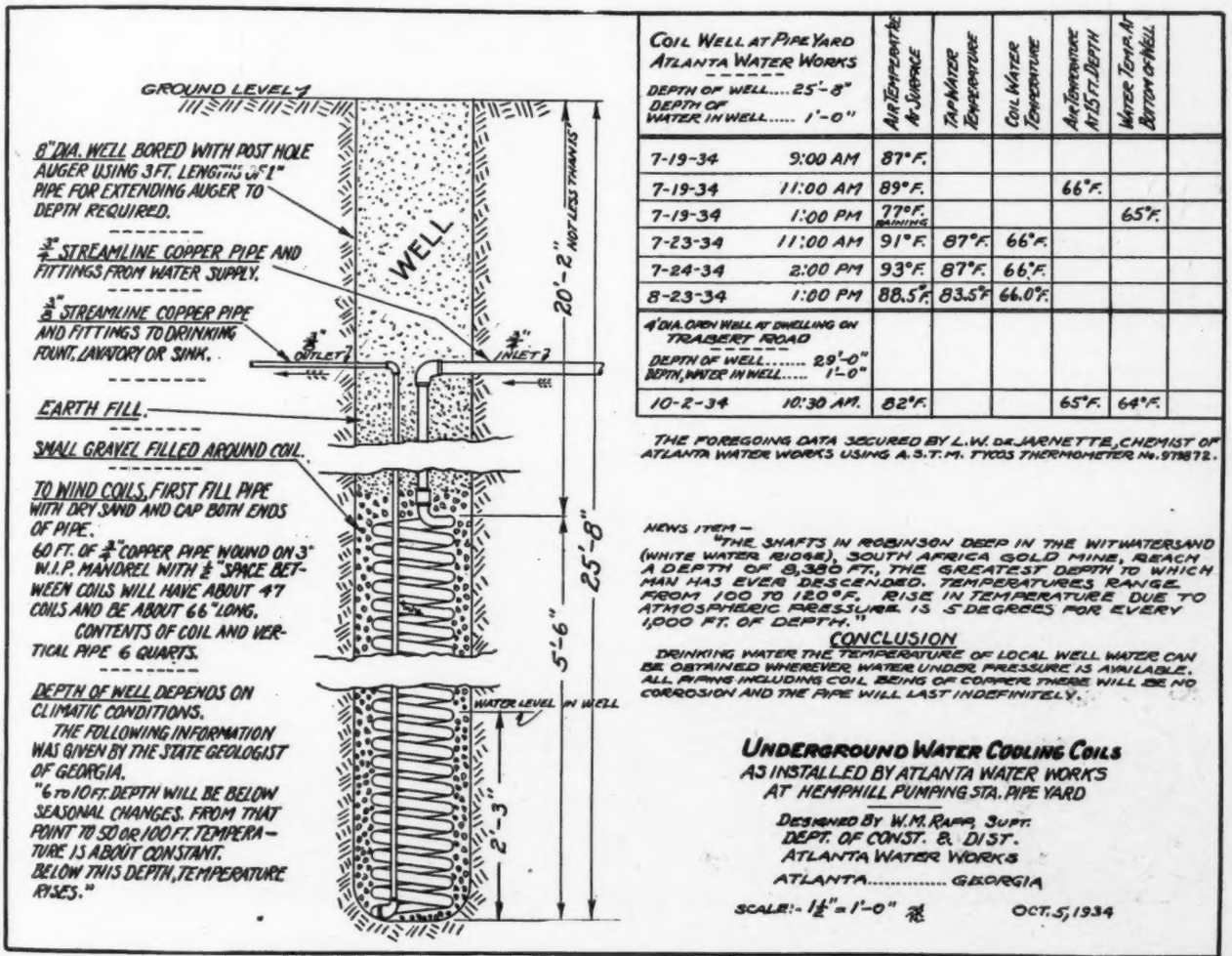
Superintendent of Distribution, Atlanta Water Department, Atlanta, Ga.

A cool drink of pure water on a hot day is very refreshing but few municipalities or private concerns are equipped nor can they afford to supply artificially cooled water to their drinking fountains in parks, on golf links and elsewhere.

The Atlanta Water Department has had two ground water-coolers, similar to the one shown in the accompanying illustration, in service for the past four years and these proved to be so satisfactory that a third has been installed. From the functioning of this last installation the data shown on the sketch was obtained.

When air temperature was 93 degrees F. the tap water temperature from the city mains was 87 degrees F., but the temperature of the water from the depth-cooler was 66 degrees F. A check up against water temperatures in wells in the vicinity showed that the warm tap water, after passing the copper coils of the earth cooler, was the same temperature as waters in the wells.

The accompanying sketch tells its own story of how the coolers are constructed and the results obtained.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ½" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN 15'
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL

COIL WELL AT PIPE YARD ATLANTA WATER WORKS — DEPTH OF WELL.... 25'-8" DEPTH OF WATER IN WELL..... 1'-0"		AIR TEMPERATURE AT SURFACE	TAP WATER TEMPERATURE	COIL WATER TEMPERATURE	AIR TEMPERATURE AT 15 FT. DEPTH	WATER TEMP. AT BOTTOM OF WELL	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4' DIA. DRY WELL AT DWELLING ON TRABERT ROAD — DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L. W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 979872.

NEWS ITEM — "THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION

DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER, THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W. M. RAPP, SUPT. DEPT. OF CONST. & DIST. ATLANTA WATER WORKS
ATLANTA..... GEORGIA
SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

Underground Water Cooling Scheme of Atlanta Water Department

BLOWING OUT SERVICE LINES*

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

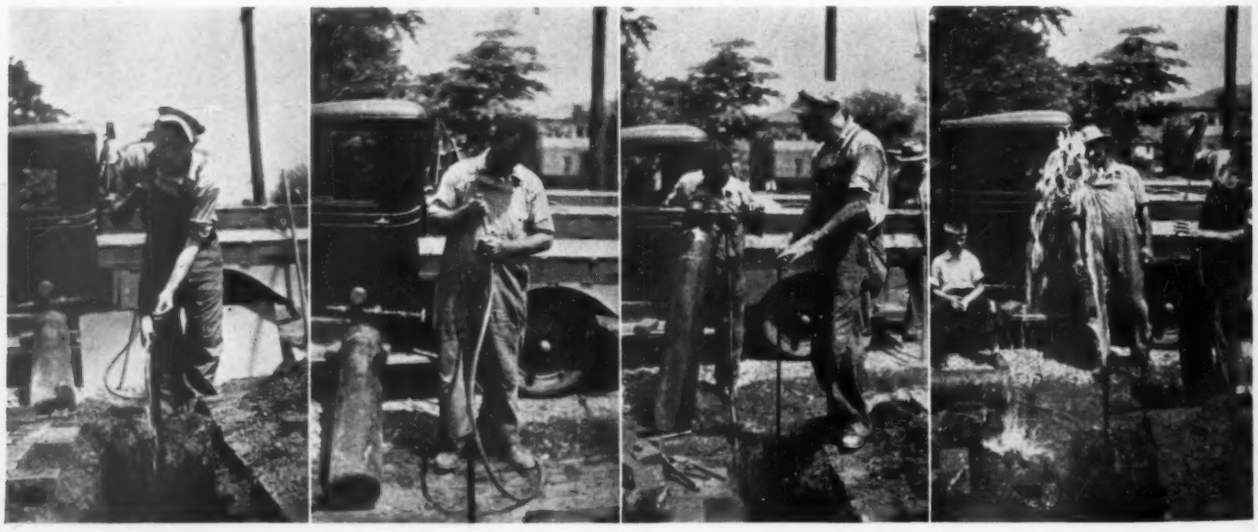
This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

*An article published in WATER WORKS AND SEWERAGE, October, 1935.



Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

THAWING FROZEN SERVICE PIPES

By REEVES J. NEWSOM

President, Community Water Service Co., New York, N. Y.

The most rapid and economical method of thawing has been by the use of electric current. The most commonly used scheme of electrical thawing has been to get the local power company to mount transformers on trucks and to connect to existing power lines in the streets. The cost of this method is apt to be greater than the use of other types of electrical equipment, but there is usually not time to get other equipment after the freeze-ups began. In outlying districts no power lines were available in some cases, and other methods had to be resorted to. Engine driven generator sets especially designed for the purpose were only occasionally available, but the modern electric welding outfit was found to have approximately the voltage and amperage range required for thawing services, and where these outfits were used for thawing mains two of them were generally used in parallel.

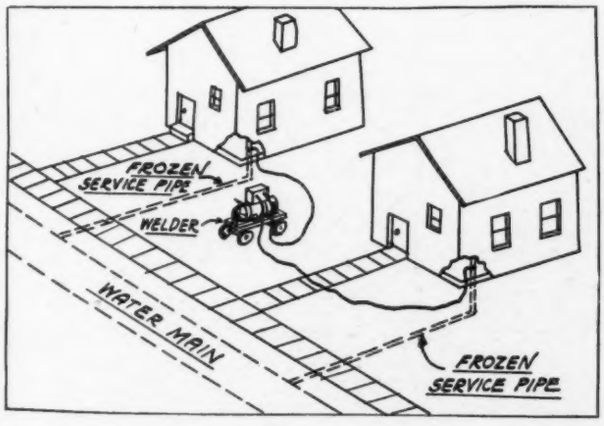
A third type of electrical equipment which was effective for short services, where connections could be made close together, was a small portable transformer with a capacity of about 150 amperes at 20 volts. On some systems a surprising number of services were successfully thawed with equipment of this type—the current being taken through the residence wiring outlets.

Where only a few frozen services were encountered or where the electricity was not available; or, where it was ineffective due to rubber gasketed couplings, new lead substitute joints in the intervening main pipe, or lack of capacity to thaw copper services, steam and hot water were used. One man can operate the steam outfits and do the thawing.

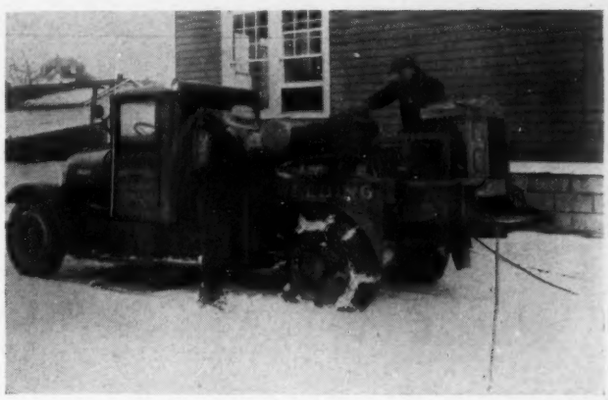
Steam is effectively used by generating it in a small portable boiler and feeding it under about 10 lbs. pressure through a ⅛-inch copper tube or 3/16-inch block-tin tubing. It is successful for only relatively short straight pipes where the steam jet can be advanced against the ice face as it melts. Where sharp bends are encountered and the tube cannot be advanced, the steam will not carry forward through the melted ice. Also, if the length of the service is too great the steam condenses in the tube before reaching the ice face and is not effective.

Hot water is, in general, more satisfactory than steam, though it requires two men to operate the equipment—one to push the tube into the pipe as the melting of the ice advances, and the other to operate the small force pump required. This method can be used on a longer service than the steam process and the hot water will carry farther beyond the end of the tubing when it meets an obstruction than does steam.

Small sections of 4-inch main about 75 ft. in length can be thawed by this method and if ⅜-inch iron pipe is substituted for the copper or tin tubing, the length that can be thawed can be approximately doubled. Where relatively new lead-substitute (compound) joints are encountered, preventing the use of electrical thawing, this becomes a valuable method of thawing larger mains also.



Sketch showing electric thawing equipment hook-up to thaw two services. One connection may be made to a fire plug, if convenient, when only one service is to be thawed. Before turning through the current the house piping is disconnected from the service line for safety.



Mobile Welding Generator Set Thawing Frozen Service Lines.

Time Required for Thawing

Experiences indicate that the time required for thawing services by all three methods varied through a wide range. Where equipment of adequate capacity was available for electrical thawing services were often thawed in from three to ten minutes and small mains in from one-half to two hours. Both hot water and steam thawing require a considerably longer time than this. However, in many instances, because of lack of experience and precedent, many jobs of thawing of both long services and mains were attempted without adequate equipment; and, as a result, two or three hours were often spent on a service and as long as ten or more hours on a main.

Cost of Thawing Operations

The cost of electric thawing was made up of many combinations of charges. In cases where hook-ups were arranged with the local power company, the charge was sometimes a stated amount per service or an hourly charge for the equipment, with or without a current charge. Welding outfits were supplied both on a per service basis and an hourly charge for men and equipment. The cost commonly varied between $2.50 and $7.50 per service for electric thawing, and the use of hot water and steam applications also came within this range. A common charge for welding outfits was $4.00 per hour, although it varied from $2.50 to $7.50 per hour.

Difficulties Encountered

One of the principal difficulties encountered in thawing by electricity has been the occasional inability to get a closed circuit through the pipe or main that will carry sufficient current to produce the required heat. The most common cause of this type of trouble is the presence of lead substitute joints in the section of main between the frozen service and whatever point is used for the circuit making connection. The weight of evidence from past experience appears to show that new lead substitute joints definitely will not carry sufficient current for thawing. Depending somewhat upon the character of the water, joints of this type in about five years will have formed, by corrosion of the iron in the bell and the material itself, a contact that will carry the current. This contact is somewhat fragile, however, and if too large an amperage is forced through it, it may burn through and break the circuit or create arcing and damage, after which other means than electricity will have to be used. To avoid this, it is necessary to keep the amperage below 200, or probably 150, and keep the current on for the extra time required. Rubber bushed repair couplings or joints are another reason for being unable to get a closed electric circuit, and, except in rare instances, time does not seem to produce a satisfactory current

One of the Mobile Welding and Thawing Units—Ottawa, Canada, Water Department.

carrying contact unless much higher voltage is available than is needed for ordinary thawing work.

Failure to ascertain that there is no other path for the current to take than through the service line may lead to failure in thawing, even though the ammeter indicates that the proper amount of current is flowing. In some cases the current has taken a path through the house wiring and has heated the small wires (and BX cable carrying them) hot enough to set the house afire. It is not sufficient merely to detach the ground wire that is customarily found near the cellar wall, because other ground connections may be present elsewhere. *A complete disconnection of the piping system from the service line, by removal of a fitting or the meter, is the only safe course.*

Necessary Consideration in Successful Thawing

The thawing of services and mains by the use of electric current will be more uniformly successful if water works operators will bear in mind the fundamental characteristics of current flow and energy transference. Amperage is the measure of quantity of current flowing and is the most important element to consider because on the one hand the heating effect desired is principally dependent upon the flow of a sufficient number of amperes of current and, on the other hand, damage to joints and pipe is caused by too great an amperage. Voltage is the measure of electric pressure which is driving the current through the pipe. Voltage is therefore important only because of the amperage which it will force through the resistance of the pipe and joints. Ohms are a measure of resistance—i.e.—electric friction. The relation between the three is expressed as Voltage equals Amperage times Ohms. Thus, the greater the resistance, the greater must be the electric pressure (voltage) to force through a given amount of current.

Resistance, therefore, if it be in the joints, is a detriment to current flow and to the thawing. But the resistance of the material of the pipe to be thawed is useful in thawing, for ultimately it is the heat, produced by the force of the current, that melts the ice, and the greater the resistance, the greater the heat produced by a given amount of current forced through.

The transference of electric energy into heat in a conductor takes place according to a law first stated by James Joule, an English physicist. According to this law, the heat produced is directly proportional to the resistance of the conductor, the square of the amount of current and time the current is flowing. Thus it will be seen that a material which is a poor conductor and offers greater resistance to current flow will get hotter than one which is a good conductor. Also, a relatively small increase in amperage will greatly increase the heat produced as the variation is as the square of the amperage increment.

It would appear from this law that any difficult job of thawing could be done by merely continuing the current flow for a long period, and to a limited extent this is true, but it must be remembered that the heat produced in the pipe is immediately dissipated by the ice inside and the cold soil on the outside. Therefore, for any rate of heat production there is a point reached where it is dissipated as fast as produced; and, if in a reasonable time the pipe line is not thawad it is safe to conclude that too much of the heat is being lost through the soil and mere continuance of this condition for a longer time will not bring success. More heat must be provided and since the resistance of the pipe cannot be controlled, increased current flow (amperage) is needed. To secure this additional flow of amperes an increase in the electrical pressure (voltage) is necessary.

As a result of this law of Joule's, it can be seen that a copper pipe, being a good conductor, can only be heated by passing a considerable amperage through it and for a longer time than in the case of other materials (such as iron) which are not such good conductors. Comparing the resistance of the various metals used for water pipes, in order, copper is the least resistant. Considering copper as 1, steel is 7, wrought iron is 9, lead is 12, and cast iron is 73. Since copper has 1/7th to 1/9th the resistance of steel and iron and 1/12th that of lead, it is necessary to put through at least twice the amperage for approximately twice as long a time in order to thaw a length of copper service pipe as is required for the same length of steel pipe.

Experience

Experience has shown that from 200 to 400 amperes (varying with the diameter) will thaw iron, steel or lead services in from three to ten minutes. Depending upon the character of the connections, the type of joints in the mains and other elements of resistance, the voltage necessary to force such a current flow through the circuit will vary from 10 to about 60 volts. To thaw mains, amperages of from 400 to 700 are likely to be required at times. In view of the larger area of metal in these pipes it is fortunate that cast-iron has high resistance to current flow, else it would be impossible to produce sufficient heat with any practical portable electrical apparatus.

To produce a current of 400 amperes at 60 volts requires about a 25 k. w. generator, although one with a capacity of 30 k. w. is better. The gasoline engine driving it should have a rated capacity of at least 50 per cent more in order to sustain the output for several hours in case difficult main pipe thawing is encountered.

If current is taken from the 2300 volt lines of the local power utility and is stepped down to 110 volts, the transformers should have at least a total of 75 KVA capacity if mains are to be thawed, because it is occasionally necessary to use higher amperages than the average stated and also to maintain the current flow for several hours. A 25 KVA transformer is usually ample, however, for the thawing of services. It has been observed that AC current is more effective than DC in thawing because the vibration set up by the former is of material aid. The necessary small amount of melting near the pipe surface takes place with less actual temperature rise in the pipe.

ECONOMY OF ELEVATED STORAGE*

By DONALD H. MAXWELL**

The operating records of the Glencoe, Ill., water works furnish a striking demonstration of economy procurable through the introduction of elevated storage. In this case the savings in pumping costs, resulting from use of an elevated tank, are sufficient to cover all annual costs incident to the project.

The Glencoe pumping arrangements and filtration plant were designed to operate in connection with an elevated tank which was omitted in the original construction and the pumps operated against direct main pressures for about 4 years. In 1932, a 500,000 gallon elevated tank was added and now records under the new conditions are available to show a saving of about 33 per cent in power consumption.

The Glencoe filter plant has two motor driven low lift pumps each of two million gallons rated capacity and three motor driven high lift pumps, of one, two and four million gallons rated capacity respectively. In addition there is gasoline engine driven standby equipment. The average daily pumpage is approximately one million gallons, the rates varying from a minimum of approximately 420,000 g.p.d. to a maximum of 3,300,000 g.p.d. The maximum hourly rate of consumption is approximately 5,200,000 g.p.d. and the minimum hourly rate is about 300,000 g.p.d.

Pumping Conditions With and Without Elevated Tank on the System

Comparison of these consumption rates with the installed pump capacities makes it evident that the high lift pumping operating against direct main pressures, with pumps throttled a considerable part of the time, was necessarily inefficient. The low lift pumping was also inefficient, owing to the desirability of maintaining a full clearwell and thus a 500,000 gallons storage. To do this it was the practice to operate the filters more or less continuously with the low lift pumps throttled. At times these pumps had to be operated at 15 per cent of rated capacity.

With the elevated tank in service the high lift pumps now operate intermittently at about their rated capacity and best efficiency. With present practice, maintaining the clearwell storage at not less than 75 per cent full, is accomplished by running one or two low lift pumps which operate at about rated capacity during approximately the same periods as the high lift pumps are in service.

Improved Pressures

The pressures maintanied in the business district when pumping against main pressures varied over an extreme range of 40 pounds per square inch. The variation was from approximately 28 pounds minimum to 70 pounds maximum. Under present conditions, with the tank in service, a very uniform pressure is maintained, having an extreme range not to exceed 20 pounds. From 35 pounds minimum to 55 pounds maximum is recorded at the business center. The changed pressure conditions are clearly shown on the pressure charts, revealing recording gage pressures before and after providing elevated storage.

Savings in Power Consumed

As now operated the pumps run at capacity from 4 to 24 hours a day depending on the season, whereas formerly they ran continuously during periods of light as well as heavy demands. Much of the time they were throttled thus producing a very considerable sacrifice in efficiency as becomes apparent by comparing the power consumption with and without elevated storage, as shown in Table I.

During 1931 (operating direct pressure) the power consumption averaged 1,835 k.w. hours per million gallons delivered to the mains. During the six months of operation with the elevated tank in service, the power consumption per million gallons

500,000 *Gallon Elevated Tank, Glencoe, Ill.*

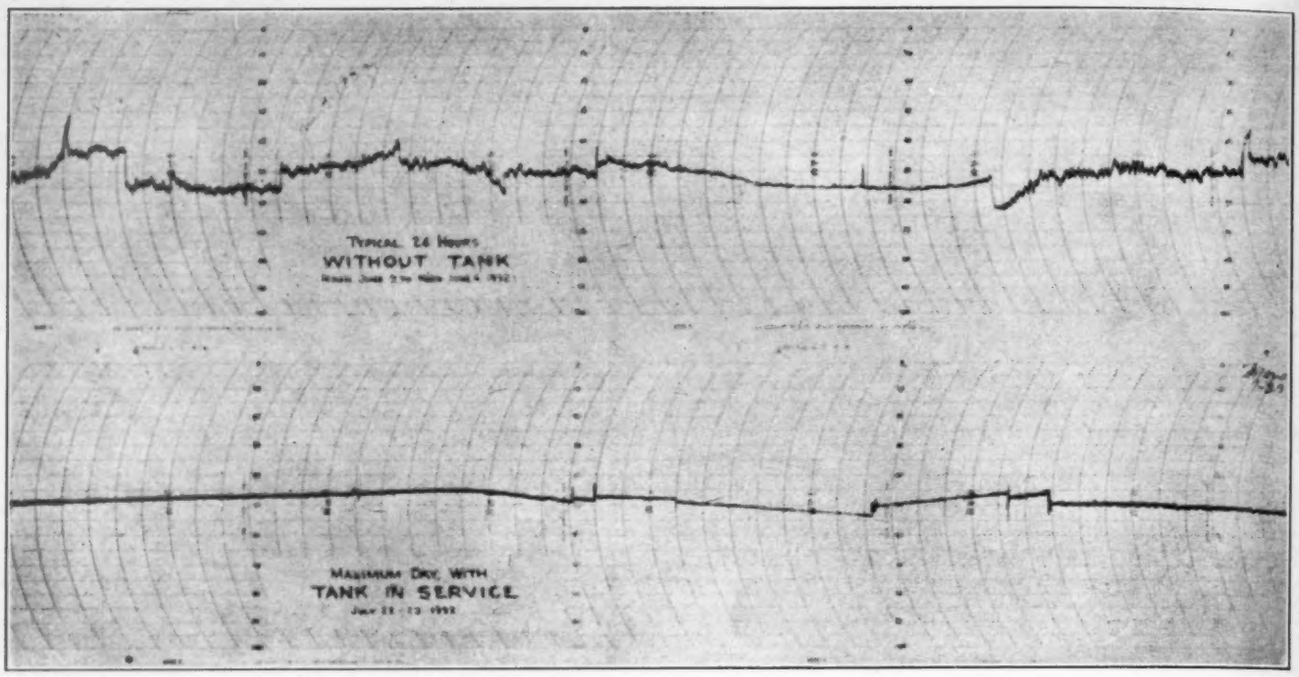
TABLE I—PUMPAGE AND POWER DATA COMPARING OPERATION WITHOUT AND WITH ELEVATED TANK, GLENCOE, ILLINOIS WATER WORKS

Month	Pumpage, million gallons	Kw.hrs. per calendar month	Kw.hrs. per m.g.d.	Kw. max. demand
1931 (without tank)				
January	21.467	47,600	2,220	87
February	17.568	40,000	2,280	78
March	20.265	45,600	2,250	81
April	22.877	47,400	2,070	126
May	29.097	55,200	1,900	174
June	37.153	60,400	1,620	192
July	55.516	80,800	1,450	249
August	56.960	79,600	1,400	246
September	34.030	62,000	1,820	174
October	27.580	59,000	2,140	114
November	23.116	50,000	2,160	102
December	22.362	47,800	2,140	99
Total or average	367,991	675,400	1,835*	
1932 (only those months with new tank in service throughout month)				
March	21.578	27,400	1,270	117
July	45.083	55,200	1,225	186
August	46.437	56,800	1,225	189
September	38.920	47,200	1,210	168
October	23.700	29,600	1,250	174
November	19.502	25,000	1,280	120
Total or average	195,220	241,200	1,235*	

*Weighted average.

*Excerpts from an article which appeared in Water Works and Sewerage.

**Of Alvord, Burdick & Howson, Consulting Engineers, Chicago.



Record Gage Pressures Before and After Elevated Storage Was in Service

pumped has averaged only 1,235 k.w. hours, almost exactly two-thirds of the former power use and much more uniform as shown by the tabulation.

The saving in cost of power due to improved operation, made possible by the tank, cannot be properly shown by direct comparison of power bills for corresponding periods under the old and the new conditions because of the fact that a new power rate was introduced some time after the elevated tank went into service, and also because there has been a decrease in pumpage approximating ten per cent.

The fairest estimate of saving in power cost is obtained by applying the new power rate to the recorded 1931 pumpage as it actually occurred for comparison against the same monthly pumpage if delivered under more efficient operation as now attained with elevated storage. The saving calculated in this manner, amounting to approximately $2,500 a year, is sufficient to cover interest on the investment, depreciation (on sinking fund basis) and maintenance of the tank.

Thus, without added annual cost, the village has been able to avail itself of the many advantages of elevated storage which includes doubling of reserve storage, better fire protection, uninterrupted and more uniform water pressure, greater flexibility of filter and pumping operations and increased plant reliability.

It is worth noting that the saving in cost of power would have been greater if Glencoe had happened to enjoy a uniform rate of power, such as applies in many plants. In reducing the power consumption by 33 per cent the plant is not able to earn proportionately as good a rate. The estimated net average power cost based on the new rate when applied as above explained to 1931 pumpage without the tank nets 1.27c per kw.h., whereas with the tank it is increased to 1.36c per kw.h.

Auxiliary Equipment

The elevated tank is equipped with an altitude valve and a remote indicating water level gage is installed in the pumping station 2⅓ miles away to make practicable the full use of the storage capacity available.

The elevated tank was supplied by the Chicago Bridge & Iron Works. The Glencoe plant is in charge of E. L. Pflanz, Superintendent, and George R. Young is Village Manager.

Old Standpipe Rehabilitated by Guniting

By V. VON GEMMINGEN

Town Manager, Culpeper, Va.

During the year 1895 the town authorities of Culpeper, Va., erected a standpipe of 300,000 gals. capacity. During its 38 years of service it had gotten into such a weakened condition from corrosion that for a time it appeared as if it would have to be replaced by a new tank or reservoir and, thereafter, removed at an expense in addition to the expense incurred in providing new service storage.

After giving some study to the matter of possible renovation of this old structure, by application of a jacket of cement mortar from a gun—"Guniting"—it was estimated that the project would cost $4,000 or thereabouts. There was a large difference between that figure and the estimated $18,000 or more which it would have cost to provide a new tank or reservoir. It was decided to proceed with the project of Guniting the standpipe and its base.

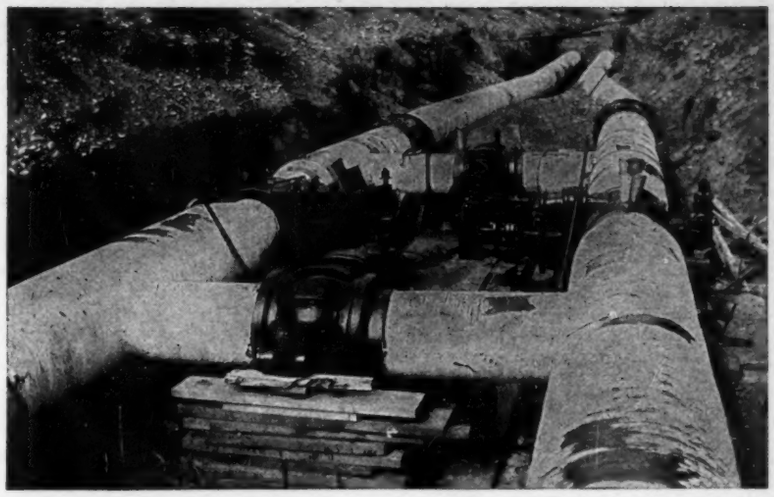
First, the town laid a heavy false bottom in the standpipe consisting of a reinforced concrete slab. The contractor* came in and cleaned the inside walls of the structure and welded the necessary reinforcing and holding wires to its sides. "Gunite" was then applied, starting with a thickness of 2.5 inches at the bottom and running out to 1.5 inches at the top. On top of this a second or "seal-coat" was applied and in *three* days water was turned back into the standpipe.

The structure has shown no signs of leakage, whereas, prior to its renovation, there were approximately 50 active leaks in the side walls, and in one spot a hole about half the diameter of a lead pencil had been eaten through the iron plate.

The standpipe rests on a rubble masonry base from which much of the cement mortar had disintegrated. This unsightly, and probably dangerous, foundation structure was also "Gunited" to produce a sightly and strong structure.

The 39 year old standpipe, which a year ago was ready to be junked as worthless, is today as serviceable as when new and apparently good for another 30 years if not longer. We feel that we have made an excellent investment in having spent $4,000 and thereby avoided an expenditure of at least $18,000—a net saving of $14,000. The "Guniting" job has been in every respect satisfactory and we are highly pleased with the results.

*The work was done by the National Granite Co.



WHY... ARMCO SPIRAL WELDED PIPE MEETS THESE SIX DESIGN-FACTORS

High Flow Capacity

Extensive experiments under control of government experts have determined coefficients of flow for continuous-interior pipe. These demonstrate that flow of water through pipe fabricated from rolled iron or steel is greater than through cast pipe. ARMCO Spiral Welded Pipe is cold-formed and electrically welded from rolled iron and steel.

Low Leakage Loss

These three things enable contractors to install ARMCO Spiral Welded Pipe free from leakage: (1) Exacting methods of fabrication; (2) tests; (3) use of flexible mechanical couplings or field-welded joints. Bottle-tightness is usually attained under imposed test pressures.

Utmost Strength and Ductility

ARMCO Spiral Welded Pipe is made of materials possessing an ultimate strength of 40,000 lbs. to 50,000 lbs. per sq. inch. True roundness of cross section plus reinforcement of the spiral weld produces a pipe that, wall-thickness for wall-thickness, is much stronger and more resistant to rupturing forces than straight-seam welded pipe.

Elongation of pipe-wall material is from 20 to 25% or more, thus proving the ability of ARMCO Spiral Welded Pipe to absorb sudden rise of operating pressure without danger of explosive bursting.

No Sudden Rupture or Breakage

Here is a typical test. Four lengths of stock pipe 20½ inch OD, 1/32-inch wall were tested to destruction by hydrostatic pressure. Test lengths were part of a run-of-mill order. No leak appeared until the specimens broke. Before rupturing, each piece increased about 10% in circumference under a pressure of 1,300 lbs. per sq. inch. All ruptures were in the plate, which demonstrated 100% weld strength.

Economical Permanence

By selecting wall thicknesses in accordance with strength requirements and service life, economic saving in material cost is effected. Initial savings over other materials are frequently large enough so that, if invested at a common interest rate, they would amount to enough to replace the line before the end of its useful life.

Greatest Service and Safety Per Dollar Cost

Original cost, installation cost, and low yearly cost of ARMCO Spiral Welded Pipe combine to provide utmost service per dollar of cost. Add to this an exceptional factor of safety and you have a pipe that cannot be equalled in the applications for which it is especially suited.

Where to Use It

Supply lines • Equalizing mains • River crossings • Outfall lines • Water purification plants • Power house piping, (a) water lines, (b) low pressure steam lines • Sewage disposal lines.

16 Advantages No Other Pipe Can Match

Various Diameters • Various Wall Thicknesses • Optional Coatings • Ductile • Strong • Mill Tested • True Round • Adaptable • Long Lengths • Standard Fittings • Special Fittings • High Flow Capacity • Low Leakage • Low First Cost • Low Job Cost • Low Yearly Cost.

THE AMERICAN ROLLING MILL COMPANY
PIPE SALES DIVISION • MIDDLETOWN, OHIO

ARMCO ARMCO **SPIRAL WELDED PIPE**

CHICAGO BRIDGE & IRON WORKS

Chicago.....2198 Old Colony Bldg. Dallas.1479 Dallas Athletic Club Bldg. Houston.....2919 Main St. Boston..1548 Consolidated Gas Bldg.
New York.3390-165 Broadway Bldg. Birmingham....1586 North 50th St. Detroit.....1551 Lafayette Bldg. San Francisco....1083 Rialto Bldg.
Cleveland....2262 Rockefeller Bldg. Tulsa.....1646 Thompson Bldg. Philadelphia..1644-1700 Walnut St. Los Angeles....1455 Wm. Fox Bldg.

Plants at: CHICAGO, ILL. - GREENVILLE, PA., and BIRMINGHAM, ALA.
In Canada: HORTON STEEL WORKS, Limited, Fort Erie, Ontario

PRODUCTS

Bins, Storage
Breechings, Steel
Chutes, Steel
Filtration Plants
Flumes, Iron and Steel
Gasholders, High and Low Pressure
Hoppers, Steel
Penstocks
Pipe, Riveted Steel
Pipe, Welded Steel
Receivers, Air
Smoke Stacks
Standpipes
Steel Plate Construction
Tanks, Elevated Steel
Tanks, Storage
Tanks, Surge
Tanks, Washwater

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks and describe location.

1,500,000-gal. Radial-Cone Bottom Tank, Aurora, Ill.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to enable us to build large capacity tanks with a small range in head. Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

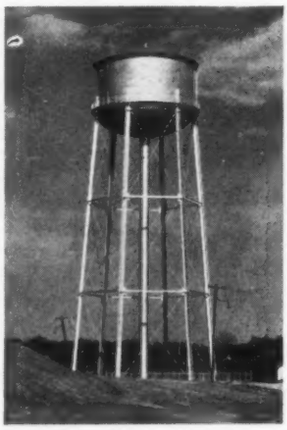
This type of tank is built in a complete range of standard sizes as shown in the table below. The diameter of the tank is relatively large and the depth shallow, reducing the variation in pressure between the upper and lower water level. The proportions of this design are also well balanced, presenting a pleasing appearance.

Ellipsoidal-bottom tanks are equipped with large steel risers riveted directly to the bottom of the tank. The size of the riser varies from three to six feet, the larger sizes being used in northern climates to prevent freezing.

ELLIPSOIDAL-BOTTOM TANK SIZES

Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20′0″	13′9″	5′0″	18′9″
50,000	22′0″	14′0″	5′6″	19′6″
60,000	24′0″	14′0″	6′0″	20′0″
75,000	26′0″	15′0″	6′6″	21′6″
100,000	28′8″	16′0″	7′2″	23′2″
125,000	28′8″	21′2″	7′2″	28′4″
150,000	34′0″	16′6″	8′6″	25′0″
200,000	38′0″	17′6″	9′6″	27′0″
250,000	40′0″	20′0″	10′0″	30′0″
300,000	41′0″	23′9″	10′3″	34′0″
400,000	47′0″	23′2″	11′9″	34′11″
500,000	51′0″	24′3″	12′9″	37′0″
600,000	54′0″	26′3″	13′6″	39′9″
750,000	54′0″	32′0″	18′0″	50′0″
1,000,000	60′0″	34′0″	20′0″	54′0″
2,000,000	80′0″	35′6″	26′0″	61′6″

Height to bottom—any even foot.



250,000-gal. Horton Ellipsoidal-Bottom tank. Kansas City, Kansas.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head and pressure variation required for washing filters. They are more dependable and economical than direct pressure washing.

RESERVOIRS

Where natural elevations are available, steel reservoirs are used for storage. They are built in standard sizes or special designs to meet your requirements, or riveted or welded construction, with or without roofs.

MORSE FILTER PLANT

The Morse filter plant is a rapid sand type plant. It is built entirely of steel in convenient sized units. The filters, coagulating basins and reservoirs are located in concentric circles, providing a compact arrangement. A 5 m. g. d. unit covers a circle 100 ft. in diameter.

SEWAGE GAS HOLDERS

Treating plants producing sewage gas have found the Hortonsphere well adapted to their operations because it permits storage of large quantities of gas under pressure without an excessive equipment investment. We also build conventional water-lift gas holders.

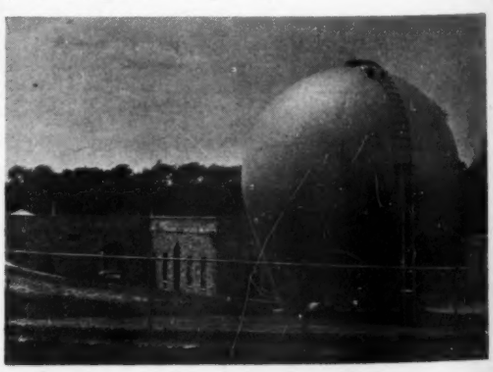
INFORMATION

We are glad to supply municipal officials and waterworks engineers with information or estimating figures. Write our nearest office. There is no obligation on your part.

125,000-gal. washwater tank at filtration plant, New Milford, N. J.

(Left) 5 Mgd Morse filter plant at Burnt Mills, Md. Self-contained unit measures 100 ft. in diameter.

(Right) 26 ft. 9 in. dia. Hortonsphere used by Beaver Dam, Wisc., treatment plant to store sewage gas at 40-lbs. pressure.



THE EDSON CORPORATION

EDSON
Reg. U. S. Pat. Off.

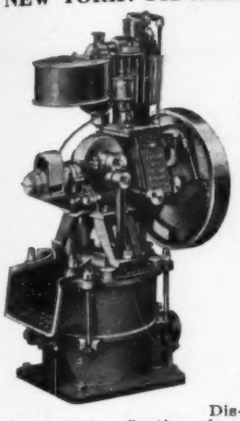
Established 1859

Main Office and Works: 49 D Street, South Boston, Mass.

NEW YORK: 142 Ashland Place, Brooklyn

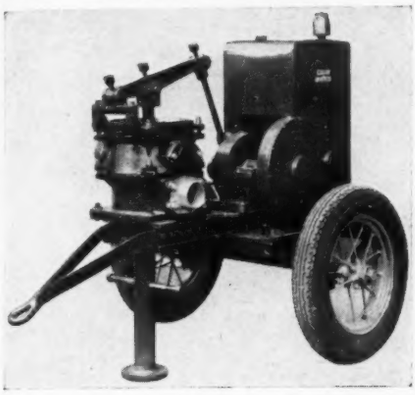
Cable Address: DIAPHRAGM, BOSTON

Manufacturers of Smallest and Largest Diaphragm Pumps in Market—FROM 2 in. suction with Open Discharge or 2 in. Suction Force Pump TO 4 in. Suction and Open Discharge or 4 in. Suction Force Pump.



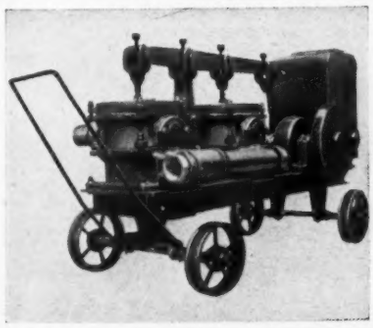
"ON TOP" POWER PUMPS

Unit	Engine	Suction	Discharge	Capacity	Weight
3-OA	1½ B	3-in.	Open	4000 g.p.h.	374
3-OA	(Mounted on Hand Skid)				395
3-OM	1½ B	3-in.	3-in	4000 g.p.h.	410
3-OM	(Mounted on Hand Skid)				431



"UT" HEAVY DUTY PUMPS

Unit	Suction	Discharge	Capacity	Weight	Code
3RMI-UT	3-in.	3-in.	4000 g.p.h.	1075	Prebend
4RMI-UT	4-in.	4-in.	6000 g.p.h.	1150	Precept
3RAI-UT	3-in.	Open	4000 g.p.h.	1025	Precinct
4RAI-UT	4-in.	Open	6000 g.p.h.	1140	Precise



"MV" POWER FORCE PUMP

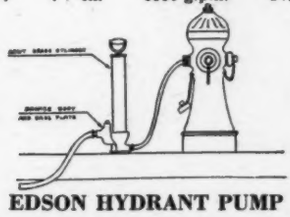
Unit	Engine	Suction	Discharge	Capacity	Weight
3RM1-2V	2 h.p.	3-in. Single	3-in.	4000 g.p.h.	900
3RM2-3V	3 h p.	3-in. Double	3-in.	8000 g.p.h.	1530
4RM1-2V	2 h.p.	4-in. Single	4-in.	6000 g.p.h.	975
4RM2-3V	3 h.p.	4-in. Double	4-in.	12000 g.p.h.	1680

ODORLESS HAND FORCE PUMPS

Size	Suction	Discharge	Capacity	Weight
No. 0	2-in.	2-in.	1200 g.p.h.	50 lbs.
No. 3	3-in.	3-in.	3000 g.p.h.	300 lbs.
No. 4	4-in.	4-in.	4000 g.p.h.	400 lbs.

EDSON HAND TRENCH PUMPS

Size	Suction	Capacity	Weight
No. 2	2½-in.	1800 g.p.h.	122 lbs.
No. 3	3 -in.	4000 g.p.h.	176 lbs.
No. 4	4 -in.	6000 g.p.h.	247 lbs.

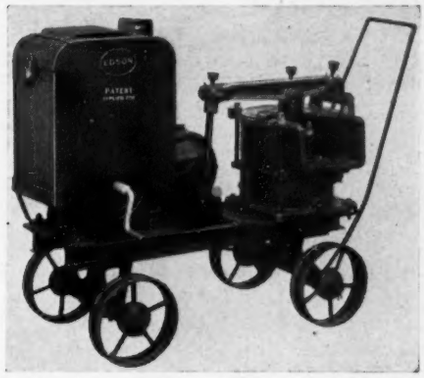


EDSON HYDRANT PUMP

Rugged bronze construction with Non-Clogging Bronze Ball Valves, complete with 10 ft. ¾" suction and 3 ft. 1" discharge hose.

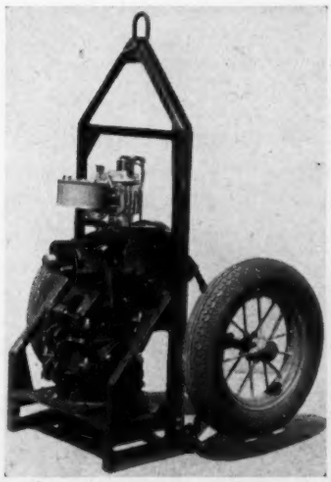
HAND PUMP— SIZE NO. 1

Smallest and most efficient non-chokable diaphragm pump made. Has 2-inch suction with open discharge and 1400 g.p.h. capacity up to 25 feet or more suction lift. Both valves brass and moulded rubber.



"AV" POWER DITCH PUMPS

Unit	Engine	Suction	Discharge	Capacity	Weight
3RA1-2V	2 h.p.	3-in.	Open (Single)	4000 g.p.h.	840
3RA2-3V	3 h.p.	3-in.	Open (Double)	8000 g.p.h.	1360
4RA1-2V	2 h.p.	4-in.	Open (Single)	6000 g.p.h.	900
4RA2-3V	3 h.p.	4-in.	Open (Double)	12000 g.p.h.	1520



"ON TOP" TRAILER PUMP

Dimensions with Trailer Upright Height 70", Width 48", Depth 40"

Unit	Suction	Discharge	Capacity	Weight
OM-T	3-in.	3-in.	4000 g p.h.	680
OA-T	3-in.	open	4000 g.p.h.	635

Also Manufacturers of Edson Pump Diaphragms, Suction Hose, Suction Strainers, Foot Valves, Adapters, Pump and Hose Accessories.

Specify Style of Pump and Size, with Length of Hose and receive our quotation on a COMPLETE EDSON PUMP OUTFIT.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

Hudson Terminal Building, New York, N. Y.

The fact is well known that most water mains are continually decreasing in carrying capacity. As they become more clogged more pressure must be exerted to keep the flow up to normal; or, if the system runs by gravity alone, sooner or later more mains must be purchased, or new sources of supply, or both, or the time will come when there will be insufficient flow to take care of the city's needs.

NATIONAL METHOD

UNLESS—

You clean the mains by THE NATIONAL METHOD, to restore them to CLOSE TO 100 PER CENT OF THEIR ORIGINAL EFFICIENCY AT A SMALL FRACTION OF THE COST OF ANY OTHER METHOD OF KEEPING THE WATER SUPPLY UP TO NORMAL.

What Causes These Mains to Become Clogged?

The causes may be divided into three classes—corrosion, growths (both vegetable and animal) and deposits, or sedimentation. Year after year the incrustations and deposits on the pipe interior get thicker and thicker, until the effective diameter of the pipe has been materially reduced.

How Does One Recognize the Fact that the Mains Need Cleaning?

In some cases the low pressure in districts indicate this. In other cases, the increased power needed at the pumps is an indication of the reduced carrying capacity of the mains. Occasionally, an unpleasant taste or odors become evident. This is a source of ill-health sometimes.

Let us suppose that it is definitely known that the mains need cleaning.

Why Choose the National Method?

Because the National method is quick and inexpensive. Because its field staff consists of experienced superintendents who can give you a satisfactory job at a minimum of expense, and with a minimum of discomfort and disruption of service.

You may furnish LOCAL LABOR if you desire. The National Water Main Cleaning Company supplies the equipment, and an experienced superintendent to supervise the work.

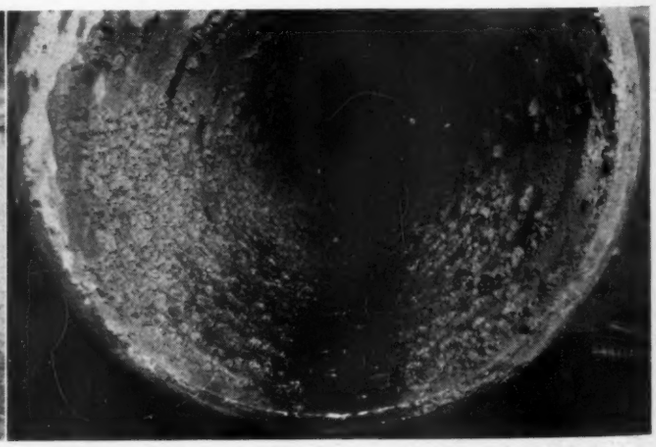
THE COST

No general figures of cost can be given. In making up an estimate of the cost of any water main cleaning job, it is necessary to take into consideration the following items:

1. Location of work
   (a) Transportation charges for men and equipment.
   (b) Location of work—country or congested district.
2. Labor conditions
3. Amount of work
   (a) Size of mains to be cleaned.
   (b) Number of feet of each size.
4. Layout of mains to be cleaned
   (a) Location of valves, and time required for complete shutoff.
   (b) Whether pipe must be cleaned in short stretches or long, because of pipe layout or condition.
5. Water pressures available
6. Depth of pipe and nature of digging

Let the National Water Main Cleaning Company give you a figure on the cost of cleaning the water main in your city. Send complete description of the conditions, and we will furnish you a quotation without obligation.

20" Main in a Midwest City Before Cleaning.



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

PITTSBURGH-DES MOINES STEEL COMPANY

Tanks—Plate fabrication—Structural Steel

SALES OFFICES AT

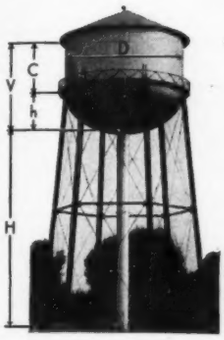
3418 Neville Island, Pittsburgh, Pa.
919 Tuttle Street, Des Moines, Iowa
Room 918, 270 Broadway, New York
1222 First National Bank Bldg., Chicago, Ill.
1223 Praetorian Bldg., Dallas, Tex.
625 Rialto Bldg., San Francisco, Calif.

In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I.—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks

Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	... ..	... ..	... ..
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.. ..	94 8	100 0	... ..	125 0	... ..	... ..	... ..	... ..
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.. ..	94 8	100 0	... ..	125 0	... ..	... ..	... ..	... ..
40,000	17	18 5	25 1	46 8	.. ..	.. ..	75 0	.. ..	96 3	100 0	... ..	125 0	... ..	... ..	... ..	... ..
50,000	19	17 7	25 7	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
60,000	19	22 6	30 6	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
75,000	21	22 6	30 6	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
100,000	24	22 6	31 0	.. ..	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4	
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7	
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2	
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0	
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1	
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8	
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7	
600,000	44	38 6	58 2	Tower heights have not been standardized for these capacities and can, therefore, be built to suit the requirements in each particular case.												
750,000	50	34 9	57 5													
1,000,900	50	52 0	73 9													

Table II.—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Elevated Tanks



Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.. ..	96 4	100 0	... ..	126 8	... ..	... ..	... ..	... ..
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.. ..	96 1	100 0	... ..	126 5	... ..	... ..	... ..	... ..
40,000	21	11 3	16 9	47 5	.. ..	.. ..	75 0	.. ..	97 5	100 0	... ..	126 2	... ..	... ..	... ..	... ..
50,000	22	13 2	19 0	.. ..	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6	
60,000	24	12 10	19 4	.. ..	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10	
75,000	26	13 6	20 8	.. ..	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2	
100,000	28	16 2	23 2	.. ..	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10	
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10	
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4	
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1	
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 1	
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0	
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 0	129 4	146 0	152 5	
600,000	55	21 9	39 7	Tower heights have not been standardized for these capacities and can, therefore, be built to suit the requirements in each particular case.												
750,000	60	22 4	42 4													
1,000,000	60	35 0	54 0													
1,000,000	65	26 1	47 7													
1,250,000	79	17 4	43 4													
1,500,000	70	37 8	60 0													
1,500,000	79	24 0	50 0													
2,000,000	90¼	22 6	50 0													

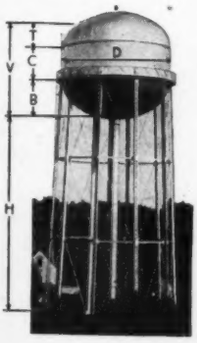
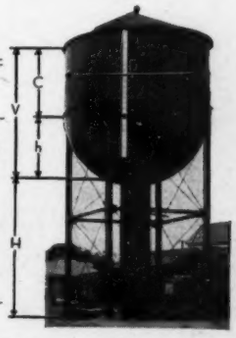


Table III.—Double Ellipsoidal Tanks

Capacity in U. S. Gallons	Tanks D ft.	V ft. in.	H
100,000	28	23 8	
150,000	34	26 9	
200,000	38	27 7	
250,000	38	33 7	Built to Order
275,000	40	33 2	
300,000	42	31 7	
350,000	44	36 6	
400,000	46	35 7	
500,000	50	39 2	
600,000	54	40 0	
750,000	Dimensions on request		
1,000,000			

Table IV.—Railroad Type Tanks

Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H
20,000	15	10 9	16 2	Any height from 15'0" to 40'0" in multiples of 5'0"
25,000	15	14 7	19 11	
30,000	17	12 7	19 0	
40,000	19	13 1	20 6	
50,000	21	13 1	21 1	
60,000	24	10 1	20 3	
75,000	24	15 1	23 10	
100,000	28	13 5	23 7	
150,000	28	14 2	24 7	
200,000	36	15 1	29 2	
250,000	38	17 3	33 3	
300,000	38	23 11	38 3	



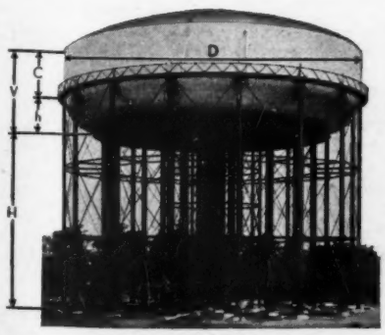


Table V.—Toroidal Bottom Tanks

Capacity in U. S. Gallons	Tank Diameter (D) when h = 10'0" and V=20'0" ft. in.	V=25'0" ft. in.	V=30'0" ft. in.	V=35'0" ft. in.	H
750,000	82 0	73 2	66 8	61 8	
1,000,000	94 5	84 3	76 9	71 0	
1,250,000	105 4	94 0	85 8	79 2	
1,500,000	115 2	102 9	93 9	86 8	Built to Order
2,000,000	132 8	118 5	108 0	99 11	
2,500,000	148 0	132 3	120 7	111 6	
3,000,000	162 0	144 8	131 11	122 1	
4,000,000	186 8	166 9	152 2	140 9	
5,000,000	208 6	186 3	169 11	157 3	

Table VI.—Steel Reservoirs

Capacity in U. S. Gallons	Diameter ft.	Height ft. in.
50,000	24	15 1
75,000	24	22 7
100,000	30	19 3
125,000	30	24 0
150,000	36	20 1
175,000	36	23 4
200,000	36	26 8
300,000	42	29 4
400,000	42	39 1
500,000	48	37 5
600,000	60	28 10
750,000	72	25 0
1,000,000	84	24 6
1,500,000	96	28 1
2,000,000	120	24 0
2,500,000	132	24 10
3,000,000	144	25 0
4,000,000	168	24 6

UNITED STATES PIPE AND FOUNDRY CO.

Burlington, New Jersey

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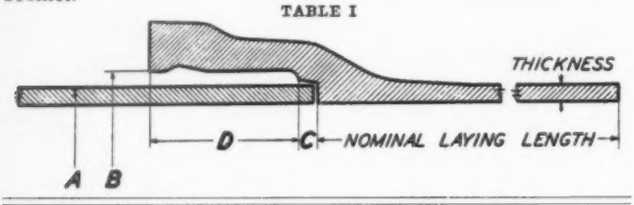
Makers of

CAST IRON PIPE AND FITTINGS
SUPER-DE LAVAUD PIPE
WEBRE SUGAR EVAPORATORS AND VACUUM PANS
CENTRIFUGALLY CAST ALLOY CAST IRON PIPE
"USICAST" CAST IRON ROOF
CHEMICAL CASTINGS
LARGE CASTINGS TO ORDER

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8		
3	250	.36	155	12.8		
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "steel pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Tentative Federal Specifications TS-2068, Type A.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Tentative Federal Specifications TS-2063, Type A)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications TS-2068, Type A)

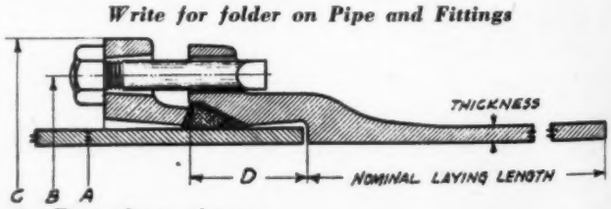
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for folder on Pipe and Fittings



1. Ruggedness of parts.
2. High resistance to corrosion since all of the joint accessories are of the same material—cast iron.
3. Maximum joint deflection without leakage.
4. Great resistance to the flow of electric currents.
5. Ease of assembly—needs only one wrench.
6. Only one gasket per joint.
7. Excellent qualities as an expansion joint.
8. Tightness under high pressures of gas or water.
9. Connection to plain end existing pipe line without use of adater.

A. WYCKOFF & SON COMPANY

81st ANNIVERSARY — 1855-1936

Manufacturers of Underground and Exposed Wood Pipe for Water and Steam
The Originators of Machine-made Wood Pipe

FACTORY AND ONLY OFFICE
70 Home Street, ELMIRA, N. Y.

REDWOOD PIPE LASTS LONG AND SAVES MONEY

Wood Stave Pipe
Protective coating omitted from pipe to show banding. Note double winding at end.

PRODUCTS

MACHINE-MADE WOOD STAVE PIPE for water works systems, sewage, paper mills, manufacturing plants, mines, railroad water supplies and chemical plants.

SOLID BORED WOOD PIPE available in various sizes.

UNDERGROUND WOODEN STEAM PIPE CASING.

WOODS USED IN WYCKOFF PIPE AND THEIR ADVANTAGES

California Redwood—Clear, all heart stock. No corrosion with age to decrease capacity; lower costs and longer life; shipping and handling costs are low and installation economical because of light weight and small units; not affected by electrolysis, soil condition, worms, insects or the famous termite of the tropics. Redwood is rot resistant.

Successfully withstands moist, hot climates, or extremely dry climates, both hot and cold, and is free from damage in all freezing weather; neither expands nor contracts with heat and cold, eliminating expensive precautions. Can be laid on ground surface or buried without danger. Delivers water as pure as at source of supply.

It has 14% greater carrying capacity than metal pipe; resists frost where severe winters raise havoc with metal pipe.

We can furnish selected Canadian White Pine or Oregon Fir Wood Pipe if specified.

Lower labor, installation and maintenance costs; long life, no electrolysis, contamination of water, or destruction by sulphur, salt water or other mineral impurities. Can be laid in wettest kind of trench; elasticity of wood prevents bursting.

New type Wyckoff California Redwood Pipe specified by *Engineers* Installed by *Contractors,* an installation being permanent, it helps sell other jobs. Wyckoff Redwood Pipe for water supply and sewage lines is a proven product.

WYCKOFF WOOD STAVE PIPE

A. WYCKOFF & SON COMPANY are originators of machine-made wood stave pipe.

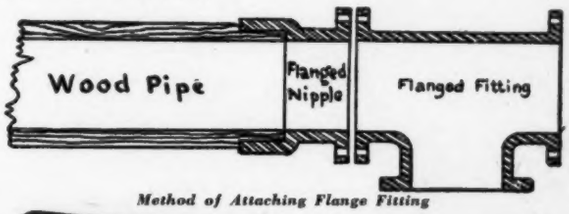
Uses—When normal or constant pressure does not exceed 172 lb.; for a supply main, from source of supply; penstocks; for carrying water highly charged with acids: for carrying heavy fluids, water supply and sewage lines, etc.

Construction—Made from woods listed above. All staves are double tongued and grooved, with faces planed, under close inspection. Staves are wound with flat bronze bands, solid hard drawn copper wire, galvanized wire, stainless steel, flat copper-steel or Toncan Iron bands or assembled with Round Rods and Malleable Iron Lugs at desired uniform tension. Pipe is rendered watertight by squeezing tongues into grooves. Montezuma asphalt coating is used as protection to the bands, or pipe can be painted with special acid resisting paint.

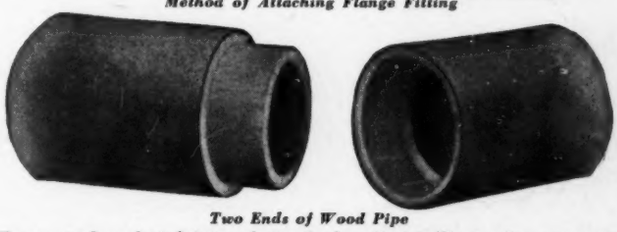
Sizes—Made in all sizes for pressures up to and including 172 lb. per sq. in. Maximum pipe lengths, 12 ft.; shorter lengths permit pipe to be laid on curves without iron fittings.

Durability of Wood Pipe—Wooden pipe has done efficient service for years in connection with supply lines, mine drainage, fume stacks, hydro-electric plants, sewage lines, conduits, etc. Pipe in use for scores of years still show perfect condition.

Joint Fittings—The Company is prepared to furnish cast iron or any kind of fittings for connecting wood and metal pipes. Wooden crosses, tees and ells in sizes up to 10-in. diameter are also available. These are made by properly boring heavy blocks cut from square timbers.



Method of Attaching Flange Fitting



Two Ends of Wood Pipe
Tenon and socket joints of wood pipe that will stand a pressure of 172 lb. per sq. in. by simply driving them together.

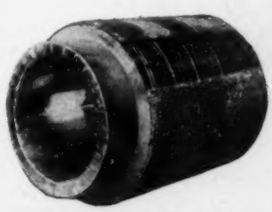
Cost of Laying Wyckoff Pipe—Cost of laying is much less than that for cast iron pipe. No special labor or materials needed in making joints. Its lightness permits easy laying.

WYCKOFF'S NEW EVERLASTING REDWOOD STEAM PIPE CASINGS

Made of 2-in., 3-in. and 4-in. single shell clear, all-heart stock California Redwood (no knots or sap) wound with heavy galvanized wire and double coated with the best uniform quality Montezuma Asphalt. This casing cannot shrink, swell or warp and is impervious to water, insects, worms and decay. It is the perfect insulation for underground steam or hot water lines and frost-proofing for exposed lines. Made with tenon and socket joints, in lengths up to 12 ft.

In ordering, always specify shell thickness desired, sizes and kinds of metal pipes to be covered. Shipment from stock. Write for details.

(All casings are tin lined for steam pressures exceeding 5 lbs.)



Wyckoff's Everlasting Redwood Tin Lined Casing

ACCOUNTING FOR PRIVATELY AND MUNICIPALLY OWNED WATER WORKS

By LOUIS D. BLUM*

Certified Public Accountant, New York City

Accounting for privately owned water companies is prescribed by nearly all states of the Union, and in connection therewith, uniform classifications of account have been prepared by the several state regulatory agencies.

While these classifications are usually compiled for the guidance of privately owned water companies, some states require municipally operated plants to maintain their records on a similar basis. The regulatory agencies require reports annually, or oftener, including financial statements and statistical operating information. The information reported becomes a public record and is available as a reference in rate controversies or other matters wherein the interests of the state or water patrons are involved.

A uniform classification of accounts for water utilities has been prepared by a committee of the National Association of Railway and Utility Commissioners. This basic feature of this classification were recommended for adoption by state commissions at the annual meeting of the Association in Atlanta in 1921. It was later revised at a convention held in Detroit in November 1922.

In some states this classification was used by privately owned water works operators prior to the states' commissions taking jurisdiction over water companies.

The Public Service Commission of the State of New York took over the jurisdiction of water companies as of July 1, 1931. Under the Public Service Law, municpalities are not required to use the uniform classification although they are required to submit reports periodically to the Public Service Commission.

In order to avoid the difficulties which would be encountered in attempting to cite differences which appear in the existing classifications of the several states, the remarks herein are made with respect to the classification adopted by the National Association of Railway and Utility Commissioners and, in the opinion of the writer, *such remarks apply with equal effect to municipally owned as well as privately owned plants.*

Bookkeeping

Books of account should be kept by the double entry method, which is generally accepted in modern business. The records to be kept by a utility should consist of general books of account together with such supporting information as may be necessary to identify and verify the records of transactions.

Balance sheet accounts should be kept for each class of asset and liability. And, in keeping with the present day accounting methods, controlling accounts should be provided for such assets as plant and property, accounts receivable, materials and supplies, investments, notes payable, accounts payable, consumers' deposits, etc. Each controlling account includes debits and credits representing the monthly total of transactions falling within the particular classification as indicated by the caption of the account. Subsidiary records should be maintained, supporting the controlling accounts in detail, which should be balanced with the controlling accounts at periodic intervals.

A pro forma balance sheet, as suggested in the classification of accounts adopted by the National Association of Railway and Utility Commissioners, is presented herewith. The accounts designated by an asterisk were selected for comment because these represent accounts peculiar to water utility operation:

Asset Side

*Fixed capital.

Current Assets:
- Cash.
- Notes receivable.
- *Accounts receivable.
- Interest and dividends receivable.
- *Materials and supplies.
- Prepayments.
- Miscellaneous current assets.

Miscellaneous Assets:
- Investments in affiliated companies.
- Miscellaneous investments.
- Sinking funds.
- Replacement fund.
- Miscellaneous special funds.
- Special deposits.

Suspense:
- Unamortized debt discount and expense.
- *Property abandoned.
- Jobbing accounts.
- *Clearing or apportionment accounts.
- *Work in progress.
- *Miscellaneous suspense.

Adjustment Accounts:
- Discount on capital stock.
- Reacquired securities.
- Treasury securities
- Profit and loss-deficit.

Liability Side

- Capital stock.
- Premium on capital stock.
- Long term debt.
- Receiver's certificates.

Current Liabilities:
- Notes payable.
- Accounts payable.
- *Consumers' deposits.
- Matured interest unpaid.
- Dividends declared.
- Matured long term debt unpaid.
- Miscellaneous current liabilities.

Accrued Liabilities:
- Taxes accrued.
- Interest accrued.
- Miscellaneous accrued liabilities.
- Advances from affiliated companies.

Reserves:
- *Retirement reserve (depreciation).
- Casualty and insurance reserve.
- Unamortized premium on debt.
- Sinking fund reserves.
- *Contributions for extensions.
- Contingency reserve.
- Miscellaneous reserves.
- Miscellaneous unadjusted credits.
- Profit and loss-surplus.

Fixed Capital

Subsidiary property records should be maintained for each classification of property to show the original cost of the property at date of installation in total; and, further analysed to show the cost of materials, labor, interest during construction, taxes during construction, overheads and other items of cost. All additions to plant account should be evidenced by job authorizations showing the estimated costs as to materials, labor, overheads, etc.

Retirements of plant should also be evidenced by proper authorizations and adjustments of the accounts made as property is taken out of service.

In order to have complete information available regarding plant additions, engineering records should be maintained, so as to disclose average costs of units installed. In addition to the money values representing plant additions, records should also be maintained as to quantities of equipment with full descriptions as to sizes, material of which constructed and locations. This information is essential in connection with the retirement of such property as mains, tanks, services and hydrants. Upon the completion of additions, an analysis of costs should be made for the purpose of comparison with estimated costs as set forth in the job authorizations.

Accounts Receivable

Accounts receivable in water utilities are usually handled by either of two methods, namely, ledger account or stub-billing. The ledger method is familiar, inasmuch as it represents the usual type of customer accounting used by most business enterprises. The stub-billing method consists of a bill with stubs attached and perforated, the detachable stubs being designed to represent the customer's account, customer's receipt and, in some cases, a delinquent follow-up notice. Bills are usually addressed by machine from stencils, and in the case of flat rates the amount of the bill is printed at the same time that the name of the customer is printed. Where the service charge is based on actual consumption the bills must be prepared and computed manually and in most cases billing machines are utilized. Upon the completion of the bills they are proved, and the ledger stub which forms the utility's Accounts Receivable record is detached. In the case of arrears, proper notation is made on the bill and

*Prepared especially for this issue by Mr. Blum, who is Chairman of the Finance and Accounting Division of the Am. Water Works Association.

ledger stub before the bill is sent to the customer, and in that manner the ledger-stub and bill always indicate the balance due. As payments are received the ledger-stubs are removed from the file and the remaining ones represent the unpaid customers' balances, which should agree in total with the controlling account in the general ledger. For further information regarding customer accounting for utilities, reference should be made to the numerous articles which have been prepared on the subject. One of the most recent articles in this connection, entitled "Utility Accounting Methods" by Mr. Raymond E. Lee, appeared in the "Journal of the American Water Works Association" for the month of March, 1936. As to the preference of one method over another, a study was made by Mr. Hal F. Smith of the Detroit Department of Water Supply, which was incorporated in a paper entitled "The Trend of Customer Accounting Practice," which is to be presented at the convention of the American Water Works Association in Los Angeles during the month of June, 1936.

Some of the manufacturers of accounting machines have developed time saving systems and usually are glad to cooperate with a utility contemplating the adoption of machine bookkeeping for either the ledger or stub-billing method.

Materials and Supplies

Store records should be kept in detail, so as to disclose full information with respect to each class of item on hand. The records should include information as to materials and supplies received, such as the date of purchase, quantity, size, price, description, and similar information with respect to materials issued. The information with respect to issues should identify the jobs for which the material was used. No materials should be issued without requisitions properly authorized. Where materials are purchased at different prices, issues may be made at actual cost prices on the basis of "first in, first out," or average prices. All returns to stores should be properly accounted for whether representing unused material returned, or replaced property fit for further use. The property should be returned to stores at the issued value unless otherwise provided for by the Utility Commission.

Property Abandoned

In connection with the destruction, abandonment, obsolesence or other extraordinary condition, it often becomes necessary for a utility to expend large sums to replace the property at a time when such loss has not been provided for through a reserve. Some commissions, upon application, may permit a water utility to charge such extraordinary expenditures to "Property Abandoned" account and amortize them through periodic charges against income over a determined period of time.

Clearing or Apportionment Accounts

These accounts are maintained for the purpose of carrying overhead items, storeroom and transportation expenses pending distribution to either expense or plant account. Ordinarily these accounts do not appear in the balance sheet at the close of a fiscal period for the reason that some commissions require that they be absorbed in transactions occurring during the year in which the expenses arose.

Work in Progress

An account is provided for unfinished construction which should include expenditures on open work orders representing additions to plant and equipment. The completed construction is cleared from this account from time to time into the regular property accounts.

Miscellaneous Expense

This account is usually charged with items with respect to which the final disposition will not be known until some future time. Types of items usually charged to this account are, tentative or preliminary surveys, designs, investigations, etc. Upon determination of the proper accounts to be charged, the items should be cleared from this account.

Consumers' Deposits

This account appearing under the caption "Current Liabilities" in the balance sheet represents the refundable deposits paid in by consumers as security in connection with the installation of service and water bills. Some commissions provide for interest on such deposits, and in such cases credits therefore should be made to the individual consumers' accounts and included in total in the balance sheet item. Where bills for service are not paid in accordance with agreements, deposits should be applied there against at periodic intervals during the accounting period.

Retirement Reserve

An appropriate reserve for retirements of plant should be maintained and increased annually in accordance with the utility's policy with respect thereto. Property retired from service, together with the cost of dismantling, less the salvage value, should be charged to this account.

Accounting for renewals and replacements of items of plant, and property representing something less than a major unit, as a rule, is a matter of policy with the utility operator. In some instances renewals and replacements under a fixed amount are charged to maintenance, whereas expenditures in excess of such fixed amount are charged to retirement reserve. Some commissions require water utilities to submit a list of the major units of property for the purpose of disclosing its policy with respect to the accounting for renewals and replacements.

Contributions for Extensions

This account should be credited with contributions made by consumers in money or property for the purpose of reimbursement of the cost of extensions of facilities. These contributions are usually required in cases where the income from extensions of plant is insufficient to justify their installation. In some cases contributions are made voluntarily and in other cases are required by the utility in connection with the giving of service. Credits to this account should represent contributions received which are non-refundable. In the event that consumers make advances to cover construction costs which are to be repaid wholly or in part, the credit should be carried in an account appropriately designated or, if the items are not sufficient in number, they may be carried in the account designated "Miscellaneous Unadjusted Credits."

Accounting for assets and liabilities other than those represented above is identical with accounting for similar items in other lines of business.

Income Accounts

Below is a pro forma income account as suggested in the uniform classification adopted by the National Association of Railway and Utilities Commissioners:

Income from Operating Properties:

Operating revenues.
Operating expenses.
Uncollectible bills.
Taxes.
  Total revenue deductions.
Operating income applicable to corporate and leased properties (carried forward).
Operating income applicable to corporate and leased property (brought forward).
Rent for lease of water plant (other)
Joint facility rents.
  Total.
Rent accrued from lease of water plant—Cr.
  Net rent deduction (credit balances in red).
Balance of income applicable to corporate property.

Income from Non-Operating Properties:

Miscellaneous rent revenues.
Interest on long term debt owned.
Miscellaneous interest revenues.
Dividend revenues.
Income from special funds.
Miscellaneous non-operating revenues.
  Total.
Non-operating revenue deductions.
  Total miscellaneous income.
Gross corporate income.

Deductions from Gross Corporate Income:

Interest on long term debt.
Miscellaneous interest deductions.
Amortization of debt discount and expense.
Amortization of premium on debt—Cr.

Miscellaneous amortization chargeable to income.
Miscellaneous deductions from gross corporate income.
Total deductions from gross corporate income.
Net income (loss in red).

Disposition of Net Income:

Sinking fund appropriations.
Dividend appropriations of income.
Miscellaneous appropriations of net income.
Total appropriations of net income.
Balance transferred to surplus.

The above form of account seems to meet ordinary requirements and agrees materially with classifications adopted by most of the regulatory commissions. However, some of the more recent classifications require that operating revenues be segregated into classifications such as metered, flat rate, public fire protection and miscellaneous operating revenues.

Expense accounts are usually segregated as to each operation which usually consists of source of water supply expenses; power and pumping; purification; transmission and distribution; commercial and new business; and, general and miscellaneous expenses. The above named operating accounts should be further broken down to show superintendence, labor, materials and supplies used, maintenance, and miscellaneous. Commercial and new business, and general and miscellaneous expenses, should be supported by sub-accounts for salaries and other items which customarily are found in mercantile or manufacturing company accounts.

Regulatory Commission Expenses

Expenses incurred in connection with transactions with governmental regulatory commissions such as fees and expenses of attorneys, engineers, employees, etc., are usually charged to operating expense during the year in which paid or incurred. In the event of large expenditures in connection with rate-hearings some commissions permit these expenses to be amortized over a definite period of years. This, however, is usually not permitted without the approval of the commission.

Uniform Classification and Municipal Plants

The accounts of municipally operated water plants are not required to be kept in accordance with the uniform classification prescribed by some of the regulatory commissions. Accordingly, the operations of municipally owned plants may appear more favorable under the method of accounting adopted by them than would result if the same method for accounting were used as required of privately owned plants. The cost of service by a municipal plant is often compared with the cost of service rendered by a privately owned plant, by advocates of municipal ownership. These advocates sometimes advance arguments that municipalities can supply service at lower costs to consumers. Upon investigation of the accounts of a particular municipality, which claims that it operates profitably, it may develop that if the plant operated under conditions comparable to a private plant, a loss from operations would result. Some of the items entering into the cost of operation of a privately owned plant which ordinarily are not considered by a municipally operated plant are: real and personal property taxes, franchise taxes, income taxes and other forms of local and state taxes. Ordinarily municipalities do not charge their income account with a provision for retirements. In lieu thereof, it is a practice of some municipalities to charge the income account with sinking fund contributions for the retirement of water bonds. Ordinarily municipally owned plants are not called upon to expend large sums for regulatory commission expenses, which in many cases are occasioned by action of the consumers in an attempt to reduce present water rates which are already fair, and eventually conceded as such by the commission. In some municipalities the interest on water bonds is provided for out of general tax revenues and does not appear in the expense account of the water department. As a result of improper accounting many municipalities render service at a cost to the consumer of less than could be charged under private operation. In some cases the operating deficits of municipally owned water properties are reimbursed out of general tax revenue which shifts the operating loss of the water department to all real-property owners. This is manifestly unfair, inasmuch as an owner of real-property who is a non-user of water must contribute through general taxes to the support of the water department, whereas the large consumer obtains water at less than cost and is thereby benefited.

The above arguments appear to justify the recommendation that the accounts of municipally operated water plants be maintained in accordance with the classification of accounts under which privately owned plants are required to keep their records. Taxpayers will then be able to decide more intelligently upon the advantages or disadvantages of municipal operation of a utility. Furthermore, valuable statistics, combining the experiences of both classes of ownership, could be compiled by regulatory commissions or other agencies. Information of this nature should prove useful and beneficial in connection with the operation of water systems.

Representative Water Rates

That where water is the dearest it has been made available at such comparative low cost to consumers is a situation stressed in its publicity releases to consumers by Los Angeles' Department of Water and Power.

What the Official Bulletin "Water and Power" has to say to Los Angeles water takers is of interest.

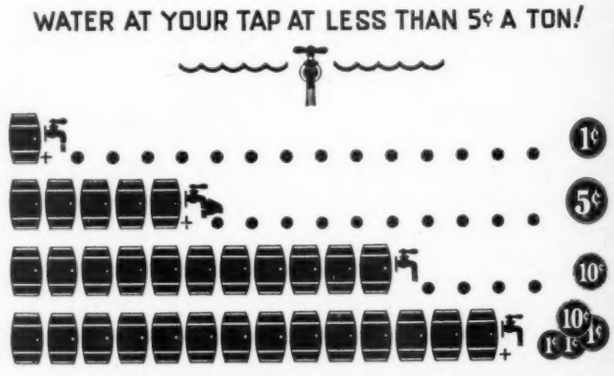
"Water and Power" has the following to say:

"Los Angeles consumers pay the low rate of 13 cents for 100 cu. ft. (750 gallons) of pure water brought in from mountain streams 250 miles distant. For the same amount of water the average charge in 183 of the larger cities in the United States is 18 cents."

The following rates charged by representative cities are cited in comparison:

San Francisco	28 cents	Youngstown, O.	20 cents
Pittsburgh, Pa.	25 cents	Miami, Fla.	19 cents
Indianapolis, Ind.	22 cents	Boston, Mass.	15.4 cents
Des Moines, Ia.	22 cents	St. Louis, Mo.	15 cents
Los Angeles	13 cents		

Any municipality which can show a rate below the 18 cents per 100 cu. ft. average in 183 representative American municipalities would do well to utilize the figures quoted, release the "story" to the local press and distribute reprints of this "news" with its water bills.



[*The above has been used by the Los Angeles Water Bureau to stress the cheapness of water at* 11 *barrels for a dime and no haulage to pay.—Ed.*]

"WATER WORKS KINKS"*

By E. E. JACOBSON[1] and CLARK CRAMER[2]

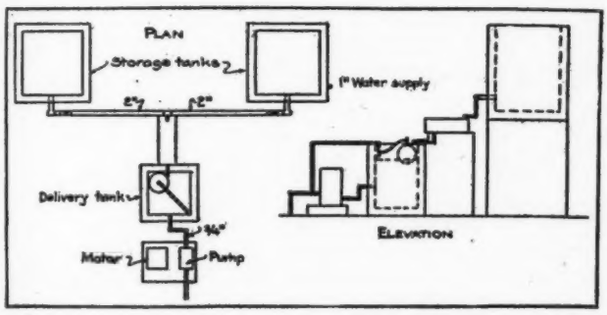
[1]*Chief Engineer and* [2]*Station Engineer*
Lexington Water Co., Lexington, Ky.

Many of the things described in this paper are not new but are from a number of widely scattered plants and in some cases are truly "kinks" in that they constitute an individual's solution of a problem that confronted him. This paper is presented with the purpose of paying tribute to the originators of these "kinks" and with the hope some of the suggestions may be of help to those who have similar unsolved problems.

We wish to acknowledge the help of Mr. Martin E. Flentje, Superintendent of Purification, Community Water Service Company, for his many suggestions, pictures and prints furnished with this paper.

Application of Chemicals

It is often necessary to improvise the means of adding chemicals to a supply at some location where it is not convenient or practical to use a dry feed chemical machine. Barrels are quite commonly used, but without a constant head orifice box the feed cannot be set so as to be relied upon, because of the variation due to a changing head. By one of the engineers of the Pennsylvania Health Department, we were introduced to a rather ingenious emergency float valve arrangement that made such a solution feeder easy to make. An ordinary barrel is set up, and to the outlet pipe is connected a heavy walled hose of any kind —a piece of common garden hose, for instance. Placing a float ball or stoppered bottle on the outlet end and cutting a slit crossways, in the upper side, of the hose, will provide a good enough means for controlling the flow into an orifice box for emergency use. When the level in the orifice box is lowered, the float will drop and gradually open the slit cut in the hose and allow more solution to flow through. When the float does



Equipment Used to Introduce Alkali, Dechlorinating or Other Solutions Into Mains, Under Pressure— New Rochelle (N. Y.) Water Co.

the opposite this slit will close and practically stop the flow—thus the constant level is fairly well maintained in the orifice box.

Pumping Constant Amounts of Chemical Solution Into a Main Under Pressure

A device is employed by the New Rochelle Water Company to apply soda ash to water under pressure. In this, use is made of duplicate storage tanks, a constant head orifice box, a delivery tank, and a plunger pump which draws from the delivery tank and delivers to the main. The pump operates against the constant head in the transmission main and, by means of a float controlled valve in the delivery tank, pumps either into the main or through a by-pass back into the tank. Thus the chemical solution added to the water in the main is just the amount fed into the delivery tank by the orifice box and the delivery tank serves as the pump intake reservoir. Designed by Mr. J. G. DeVeau of the New Rochelle Water Company, it has been successfully used for a number of years.

Applying Chlorine Directly From Cylinders to Reservoirs

Chlorination of distribution reservoirs or impounding reservoirs is often desirable. This can, of course, be done by the use of chloride of lime, or such compounds as HTH, Perchloron, etc., but these are not always available, whereas practically every plant has on hand liquid chlorine in cylinders. Chlorine gas, however, must be fed into water at considerable depths, and anyone who has tried to apply it from a boat or under shallow depths will know what a disappointment such a procedure is. To Messrs. Ed Trax and Gerrit Buchanan of McKeesport, Pa., goes the credit of having developed a means of using gaseous chlorine under such conditions. A chlorine delivery hose is connected to the chlorine cylinder placed forward and reclining in the boat. The hose is run to discharge chlorine just below the propeller blades of an outboard motor. Such an arrangement with the outboard motor operating at a fair speed will prevent chlorine from coming to the surface, even when sufficient chlorine is applied to freeze up the outlet end of the hose†.

Laboratory Kinks

Use of Aluminum Foil to Cover Bacterial Sample Bottles

The use of cloth over the tops of water sample bottles is well known, and a number of laboratories have long used a lead or tin foil that does quite well in protecting the sterile top in handling. It is probably not so well known that aluminum foil can be obtained and used for this purpose, and that it is very satisfactory. A foil having the following dimensions has been found very satisfactory, and each square can be used for several shipments, if handled with reasonable care.

Foil for ordinary 2 oz. glass stoppered water sample bottles: Alcoa Aluminum Foil can be had in sheets of .0015 in. (thickness) and 5 in. square (Aluminum Co. of America). One pound contains approximately 300 sheets and the price is very nominal, being approximately 80c per pound.

Standard Lime Solution

A saturated lime solution may be used as a standard for measuring the lime required to correct the pH of a certain water or for any such practical purpose, such as softening, without weighing and going to the trouble of making up an absolutely standard solution. One cc. will contain 2.2 milligrams of lime or 1cc. equals practically 10 p.p.m. if applied to 200 cc. of water sample. The addition of a coagulant will assist in clarification of the saturated lime water which can be thus filtered through absorbent cotton.

Running Iron Tests

In laboratories not having permanent iron (color) standards, it appears to be common practice to set up a series of standards of different increasing values for each test or series of tests for iron. It is possible to make such determinations without using more than one standard tube, by simply adding the acid, permanganate and thiocyanate to this one standard and

*Selected "Kinks" from an article in WATER WORKS AND SEWERAGE, June, 1934.

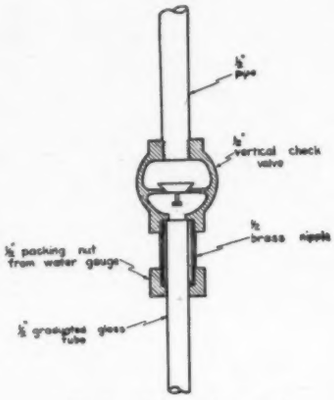
†A word of precaution is in order. Chlorine ice blockage of the hose outlet may cause sufficient pressure on the hose to result in rupture. Heavy pressure hose and some form of pressure indicator should be employed. Ye Ed. speaks from experience—almost disaster.—Ed. Note.

then adding increasing quantities of the standard iron solution to it. By comparing the solutions under test in the order of increasing iron content considerable time and labor can be saved. This method is not absolutely correct, checks made on if according to Standard Methods indicating a possible error of approximately 10 per cent.

Plant Equipment

Measuring Sludge in Basins

Measuring the depth of sludge in a settling basin and determining its character is often desirable in a water plant. For this purpose, at the Lexington Water Company plant the following device has been developed. A Crane air-release valve is connected to a standard coupling into which is packed an ordinary boiler gauge glass tube of any desired length. Lowering this slowly into the basin displaces the air in the tube through the release valve and collects a representative sample of the sludge and water in the basin. In drawing it out the release valve prevents air from entering and confines the sludge and water giving a visual picture of the basin contents at various depths. The tube can then be emptied by simply upending it.



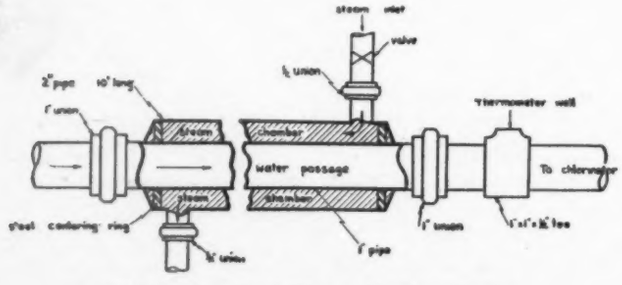
Sludge Measuring and Sampling Device

Control of Filtration Rate in Old Tub Filters

Many old filter plants still have wooden tub filters or other types, on which no controllers were placed when installed—or if installed, have become obsolete and unworkable. This had happened at the Lexington, Kentucky, plant and controlling the rate of filtration in these filters presented quite a problem. Finally a practical substitute scheme was hit upon in which the constant level automatically maintained in the settled water basins ahead of the filters was utilized. By actual measurement the influent valve to each filter was set so that the water coming in could not exceed the accepted rapid sand filtration rate. The effluent valve is then so operated that the water in the filter tub is maintained at a constant level. The filter is washed when the effluent valve has reached the wide open point and the level of water in the filter box begins to rise above the fixed level.

Water Heater for Chlorinators

In sections of the country where the water temperature drops below 40 deg. F. chlorine ice usually forms on the inside of the bell-jar on the Wallace & Tiernan chlorinator. At the Lexington plant this trouble has been overcome by heating the supply of water to the chlorinator. The heater is made by welding a 10 inch section of 2 inch pipe over a 1 inch pipe, the steam being admitted into the chamber formed between the two pipes. A thermometer in the outlet of the 1 inch pipe, which indicates the temperature of the water to the chlorinator is very important so as to control the steam and not let the supply water become so warm as to affect the hard rubber. The heater is by-passed during the warm months, and has proved most effective during the winter weather.



Chlorinator Feed-Water Heating Device

Water Ejectors

Feeding solutions such as chemicals with water ejectors has caused trouble in many plants. This is not an economical method of feeding chemicals but under certain conditions is the most practical. In one plant the method of operating the ejectors was greatly improved by increasing the size of the 1½ inch discharge line to 3 inch and replacing in the discharge line all 90 degree ells with 45 degree ells or long radius bends. The discharge line should be so erected that a cleaning rod or long handle wire brush can be pushed through the pipe occasionally for cleaning without moving the equipment such as alum tanks or taking out the discharge pipe line.

Distribution Kinks

Thawing Fire Hydrants

In extreme cold weather in Lexington, Kentucky, occasionally trouble is had with frozen fire hydrants. The Lexington Water Company supplies each piece of the city's fire fighting equipment with a rubber stoppered quart bottle of concentrated sulphuric acid in a wood box. When the firemen find a frozen hydrant they pour the acid in the hydrant barrel through the hose nipple. The acid creates heat which dissolves the ice and the water pressure washes both melted ice and acid from the hydrant barrel. A frozen hydrant can be placed in operation in less than 2 minutes by the use of the acid. It has not been found that the acid after such short contact has any ill effect on the hydrant parts.

Pipe Wrench With Bent Handles

Turning pipe and fittings in the bottom of meter boxes or small vaults is inconvenient to say the least. Pipe wrenches with handles bent at 90 degrees from the side of the wrench and extension tee-handles welded to the end of the handle simplifies the pipe work in these close quarters.

Freezing Lead and Soft Copper Service Pipe

On house service pipe lines it is often necessary to make a repair between the main and the curb cut-off. In most cases it is not practical to get to the cut-off at the main or cut off the water in that section of town. Repairs may be made by freezing the lead service with a mixture of ice and salt, providing there is no flow through the service line.*†

Although not recommended for permanent repairs, wooden pegs made of soft poplar wood make very good emergency temporary repairs.

Cleaning Metal Meter Parts

When repairing meters the most difficult parts to clean are the intermediate gears and the register gears and dials. The method used by the Lexington Water Co. is to dip the gears in nitric acid, then dip in warm water, dip next in a half and half solution of nitric acid and sulphuric acid, washing again in warm water. The gears will be clean and bright after this acid treatment.

In conclusion the authors of this paper wish to make clear that all of the "kinks" set forth in this paper are not original at Lexington, Kentucky. However, most of the "kinks" outlined have assisted in solving certain problems in Lexington. No doubt every plant operator and water works superintendent has short cuts and ingenious devices for accomplishing certain things which would be a material benefit to other water works men. The authors hope that by the presentation of this paper it will lead to the publication of many more water works "kinks" and better ones than herein recorded.

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*†Solid carbon dioxide (dry-ice) may be utilized for more rapid freezing of services by placing it on and around the side of the pipe if care is taken in handling, to preclude frosting of fingers.—Editor.

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\ A\ w$$

And, the mass of water is found to be

$$M = \frac{A\ L\ w}{g}$$

Then:

$$h\ A\ W = \frac{A\ L\ w}{g}\ a$$

Or

$$a = \frac{h}{L}\ g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

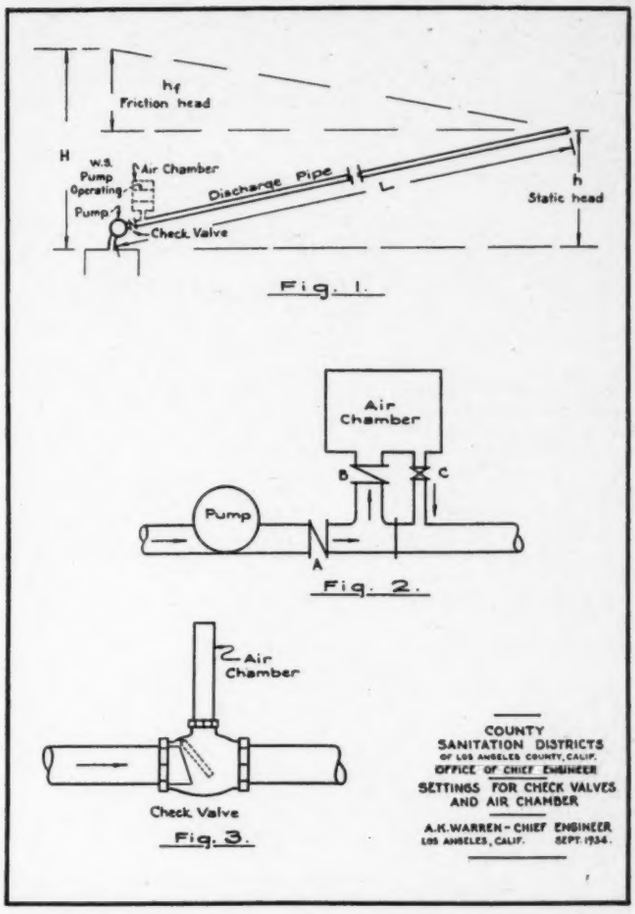
If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly*. One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large: and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.



Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B". "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

USE OF INHIBITORS IN CLEANING METALLIC PIPE

By ALLEN ABRAMS* and C. L. WAGNER*

Rothschild, Wis.

Water pipes in certain sections of the country are likely to become clogged by corrosion or deposits from the water. In many cases this has required replacement of the pipes, a procedure which is often costly due to the necessity of tearing out walls and floors. As a result there have been attempts to clean pipes by the use of muriatic or other acids with the intent to leave the acid in just long enough to remove the scale and yet not long enough to attack the pipe itself. This, however, is a questionable expedient and may be more expensive than the replacement of the pipes.

During the last decade considerable interest has been shown in the use of inhibitors in pipe cleaning operations involving acid treatment. These are usually nitrogenous materials such as aniline or pyridine; and, even glue and flour have been used. When small quantities of such substances are added to an acid solution the resultant mixture will attack rust or scale but will have practically no effect on the pure metal itself. Wide use has therefore been made of this principle in the acid process of "pickling" metals to effectively remove scale while rendering the loss of metal underneath almost negligible.

An example is also given of the use of this principle in cleaning the pipes of a thirty-five story office building located in downtown New York.[1]

Many of the pipes were concealed behind expensive marble walls and it was estimated that it would cost between $100,000 and $300,000 to replace this piping, not to mention the serious inconvenience to tenants. By the use of an acid-inhibitor combination the whole cleaning operation was carried out on Saturday afternoon without inconvenience to the tenants. The pipes were returned to practically their normal condition of carrying capacities and the cost of the operation was but nominal.

This method attracted our attention in 1927 and we made initial tests to determine how effectively inhibitors would reduce the action of acid on the metal. In parallel tests on galvanized iron pipes 16 per cent muriatic acid was used alone, to compare with the same acid containing 3 per cent of an inhibitor. Equal lengths of pipe were allowed to stand in each solution for six hours. At the end of that time the pipe in muriatic acid had lost 50 per cent of its weight while that in the inhibited acid had lost but 0.2 per cent of its weight. We were then satisfied that the inhibitors would effectively prevent destruction of the pipes by such acid when submerged for a relatively short period.

Working Demons Fractious

Not long afterwards two lengths of pipe, leading from the basement of our main office to the second floor became filled with rust and other deposit, completely stopping the passage of steam. It would have been relatively expensive to replace this piping and we therefore opened the two lengths at the top and cleaned them by pouring in inhibited acid, allowing it to work its way through. One overnight treatment, followed by a thorough flushing was sufficient to clean these pipes and no further trouble was encountered.

Early this year the Marathon County Board decided that it would be necessary to tear out and replace all the water piping in the Mount View Sanatorium due to the fact that it was so stopped up that it was impossible to get an adequate water supply through the system. When the matter was brought to our attention we suggested that an attempt be made to clean several lengths of this pipe and a decision could then be made as to the further course to be pursued.

Twenty-five gallons of 14 per cent muriatic acid were treated with 3 per cent, by volume, of the inhibitor.†† The treated acid was placed in a barrel to which was connected the suction of a small rotary pump. The acid was then forced upward from the basement to the second floor through a length of one-inch pipe, thence through a cross-over and down through another length of pipe to the basement. The returning acid passed through a fine screen to remove any dislodged particles and thence to the solution barrel.

At the beginning of the test a considerable amount of solid material was dislodged from the pipes and it was almost impossible to force the acid through. The pipes were then opened on the second floor, the acid mixture was poured in and allowed to flow by gravity until the pipes were filled. The bottom openings were plugged, the acid allowed to stand for eight hours and the acid withdrawn and the pipes thoroughly flushed. Examination indicated that the scale had been practically completely removed.

Control Procedure

In order to determine how effectively the cleaning was being done, three 6-inch lengths were cut from a 1-inch pipe, which was so clogged with rust and dirt that it was barely possible to get a pencil into the opening. One of these pipes was retained without treatment and the other two were connected in the circuit through which the acid was being pumped. At the end of about two hours one length of pipe was removed and found to be almost completely clean except for small patches of rust on the walls. After ten hours the other length of pipe removed for examination proved to be entirely free of rust and scale and there was no apparent action on the metal itself.

In the cleaning operation approximately 2,800 feet of pipe were treated, ranging from ½ inch to 4 inches in diameter. Estimates by George Baumgardt, who was in charge of the plumbing work, showed that the total labor costs were $870, while the cost of acid and inhibitor was approximately $20—a total of $890. Mr. Baumgardt estimated that the cost of replacing the piping would have been:

Galvanized pipe fittings and valves	$1,000
Labor for installation	5,000
Plaster, concrete floor and repainting	2,500
Total	$8,500

*Department of Research and Development, Marathon Paper Mills Co., for which the senior author is Technical Director. Mr. Wagner is chemist.

[1]"Removing Rust from a System with Piping Acid," F. N. Speller, E. L. Chappell and R. P. Russell—Chem. and Met. Engineering, July, 1927.

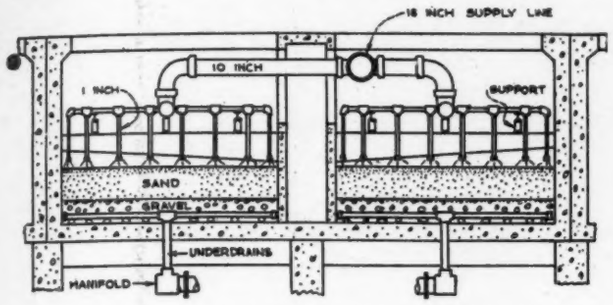
††Inhibitors are available, from several of the larger chemical companies—Barrett & Co., Monsanto Chemical Co., General Chemical Co., et al.

AN IMPROVED METHOD OF FILTER WASHING*

By JOHN R. BAYLIS
Associate Editor, Water Works and Sewerage

Probably the main advantage of the very high rate of wash, is that it lessens the tendency of mud balls to clump together in the bed.

There is an advantage in using a rate of wash which will lessen the tendency for mud balls to clump together, and if no other or a more effective method is going to be devised to keep filter beds clean, then it is advisable to use a 35 to perhaps 50 per cent expansion of the filter bed. Warning should be given, however, that this rate of wash will not prevent the formation of large

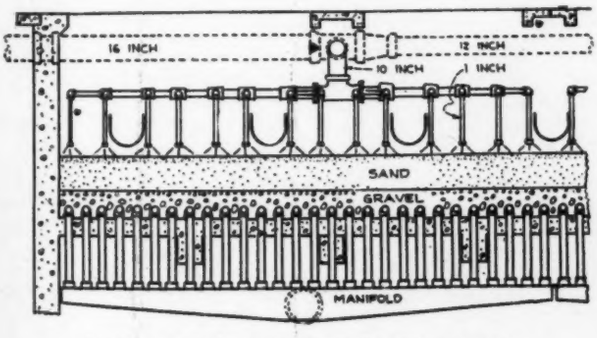


Typical Section of Filter with Surface Wash.

clogged places in many, if not most filter beds. Furthermore, where this is the case, there is great danger of disturbing the gravel layer when employing a very high rate of wash.

There is so much danger in the use of rates of washing which will expand the bed in excess of 40 per cent, that such a procedure should be used only where the beds are watched very closely and the clogged areas are dug out as soon as it is known that they have formed.

When the rate of wash is less than 25 per cent, the mud balls will at first remain within the top 2 or 3 inches of the bed, and if they become very numerous, which they do at certain times in most filters, they are so close together, they may touch each other. After the filter is put back into service, the pressure on the bed, due to the loss of head increasing, combined with additional coagulating material being deposited around the mud balls, may cause them to agglomerate to form a large mud ball. When the mud balls are formed to considerable size from a combination of a number of smaller mud balls, they have considerable sand



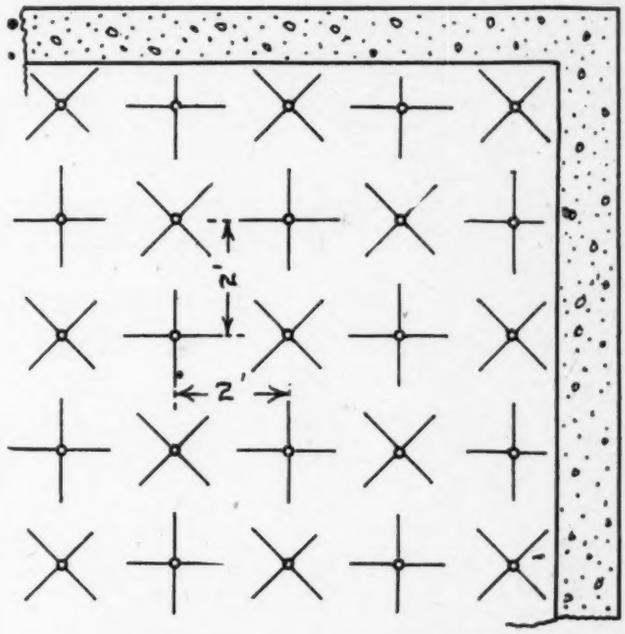
Typical Section of Filter with Surface Wash.

encased in them, which usually makes them heavy enough to force their way to the gravel surface during the washing period, even though there is not much expansion of the bed.

The writer has observed mud balls several inches in diameter on the surface of filters in two or three filtration plants. Where such large ones form and do not sink down into the bed, it is due to the fact that they are built up in a manner which encases very little of the sand; that is, they are not the result of a number of mud balls uniting, but to individual mud balls gradually gathering material and increasing in size. Very large surface mud balls probably are due to lack of properly conditioning the water before it reaches the filters, or to a poor washing system. They are usually found where a large amount of the coagulated material reaches the filters.

The Surface-Wash Method

The surface-wash scheme involves the installation of a system of pipes located over the sand bed in a manner to project jets of water under considerable pressure into the upper sand bed while it is being washed. The accompanying sketches illustrate a surface washing system which has given satisfactory results.

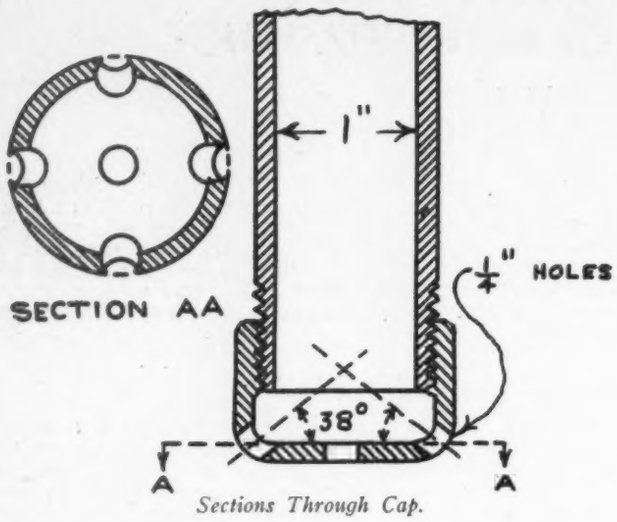


Arrangement of Jets in Surface Washing System.

The surface wash water manifold may be passed along the center of the filter above the wash water troughs with laterals taken off approximately 2 feet apart. The pipes may be supported by the troughs or by supports at the top of the filter tank. At about 2-foot intervals, 1 inch pipes project downward to within 4 inches of the surface of the sand. Caps, preferably of brass, are screwed over the ends of the pipe. The caps are perforated with 3/16 to 1/4 inch holes. Four of the holes are made to project the water at an angle of about 35 to 40 degrees to the horizontal, and at right angles to each other. The 5th hole is in the center so as to project the water vertically downward. If the lateral pipes are 2 feet apart and the downward jetting pipes also are spaced 2 feet apart, this will give 5 jets of water to every 4 square feet of filtering surface.

There may be differences of opinion as to the size and number of holes and the spacing of the jets and the illustrations are offered merely as suggestions of a suitable system. Where there is very little tendency of the water to form mud balls, the surface wash system need not be as elaborate as it should be for some other water which readily forms mud balls. It is evident that the pipes and cap may be smaller than are here shown if there is a high pressure of water, or if the pipes are located closer together. There is some question as to the pressure which should be applied. It should preferably be greater than that ordinarily used for washing filters when the water is applied under-

*Excerpts from an article by Mr. Baylis, "Washing Rapid Sand Filters"—WATER WORKS AND SEWERAGE, July, 1935. The surface wash scheme described was developed by Mr. Baylis and proven in the Chicago Experimental Filters.



Sections Through Cap.

neath the filter bed. A pressure gauge connected to one of the laterals should show a pressure of at least 10 pounds. Usually this is greater than the pressure available from the wash water tank, and water from some other source must be arranged for in many instances.

Amount of Wash Water to Be Applied Through the Surface Wash.—No definite rule can be set for the amount of water which should be applied through the surface washing system. The rate for some filters may be as low as 2 to 3 gallons per minute per square foot of filtering surface, or it may be as high as 7 to 8 gallons for unusual conditions. If there is no knowledge of the amount which should be required, the pipe system and supply arrangements should be made large enough to apply about 8 gallons per square foot per minute. About 5 gallons per minute will be sufficient for most conditions. If it is desired to increase it, drilling the holes slightly larger or increasing the pressure will be satisfactory; but, if it is desired to decrease the amount, new caps will have to be placed over ends of the pipe.

Summary

Conventional methods of washing rapid sand filters heretofore employed have not kept the beds in satisfactory condition.

An agitating force which will break up all mud balls as soon as they form is essential for keeping the sand bed in good condition.

The rate of wash necessary to give 50 per cent expansion of the sand will not keep the filter beds in most plants in a condition to be desired. There is no rate of wash which may be wholly applied from beneath the bed which will keep the filter bed in a desirable condition.

A surface wash (scouring wash) in conjunction with a moderate rate conventional up-flow wash appears to be a practical, economical method of keeping filter beds in good condition.

Water under 10 to 15 pounds' pressure applied through 3/16 to 1/4 inch jet orifices located about 4 inches above the sand surface (when filter is not being washed) to give about 5 gallons of water per square foot per minute will be sufficient for most filters.

The application of wash water beneath the sand in the conventional manner should be enough to give an expansion of about 20 to 30 per cent to the bed at a time when the surface wash is shut off. The combination of both washes usually will require but 12 to 20 gallons per square foot per minute, and this is not so great as to cause loss of sand over the wash-trough edges.

Reconditioning Filters*

By MAX U. PRIESTER

Supt. of Filtration, Suburban Water Co., Verona, Pa.

The problem of keeping filters in good condition is one with which most every plant has to deal. I will give you briefly the procedure used in reconditioning the filters at our plant, and some of the results obtained.

In general, all the filters at our plant were in such condition that ordinary raking had little effect on them. The sand was stained and coated with manganese and iron. Mud-balls, and hard spots existed all through the filter. The sand would crack and pull away from the walls and had a tendency to build up at the ends of the filter and it was impossible to keep the surface level. Organic material was deposited all through the sand which even after routine washing gave off offensive odors.

In the reconditioning process used at our plant the filter was first washed in the ordinary way. The water was then drawn down to within approximately 30 inches of the sand, and a solution of chlorinated lime was added and thoroughly mixed with the water. From 15 to 20 pounds of this material was used, representing a dosage of approximately 50 parts per million. The filter was allowed to filter to waste long enough to draw the chlorinated water down into the sand and gravel. Then the filter was allowed to soak about 48 hours with this solution thoroughly saturating the sand and gravel. At the end of this period the filter was given a very short wash, then drained empty and the sand dug into furrows to allow as much air as possible to be in contact with the sand. A filter was usually allowed to stand this way for a day or so to obtain as much drying as practicable.

After this the sand was leveled and another washing given it. A connection was made to a fire hydrant on the high pressure line by means of a fire hose. This was reduced to a 1 inch hose and to the end of this was attached a 1 inch pipe about 8 ft. long. The filter was washed at a very low rate, just enough to have a flow into the wash troughs, and the pipe wash was begun. The pipe was handled by two men and continually brought up and down in the sand bed. It was pushed down to the gravel and brought up again over the entire bed. Thus the whole bed of sand was completely agitated and the pressure was in every part of the bed and carried down through the gravel with every vertical and horizontal movement of the pipe. A certain amount of care had to be taken to be sure that the gravel was not dislodged by this treatment. Incidentally, I might say that a 2 inch pipe was tried, but due to the pressure and weight it was too cumbersome to handle and greater efficiency was obtained when using the 1 inch pipe.

When the washing was started the visible effect was astounding. Heavy dark clouds of manganese, mud, etc., were washed out. With every downward plunge of the pipe there seemed to be a cloud of material stirred up and carried away by the wash water. A small amount of sand was lifted into the wash troughs, but no appreciable amount. Finally after the filter had been thoroughly flushed all over, the water began to clear up and when the entire bed was cleared the pipe washing was stopped. We were then unable to locate any hard-spots or mud-balls. Upon examination the sand was visibly cleaner, the bulk of the stain had been removed and the sand was left over the entire surface of the bed.

After the filter had been put back in service the effect of the special wash was more convincing. The filter washed much easier and cleaner. There was no cracking of the sand or pulling away from the side walls, and above all, the bed was absolutely free from odors. A very noticeable effect observed was that of increased length of filter runs.

On one filter chlorine was used. In this procedure the filter was filled to capacity and heavily dosed with chlorine gas. After as much gas as possible had been put into the water, and the water was drawn down into the sand and gravel. The remaining steps in the procedure was the same as when chlorinated lime was used. The results were practically the same. This method of reconditioning filters is not difficult, and yet it is very effective. Naturally, it is not a cure-all for all filter troubles, but the life of the filter and its effectiveness when in use is well worth the time and effort required to apply the treatment.

[*The above procedure is very similar to that effectively employed at the Atlanta, Ga., plant which involves routine filling of the beds at 10 to 14-day intervals with chlorine solution. After 24 hours standing the unit under treatment is washed. Only one unit is treated at a time.—Ed.]

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

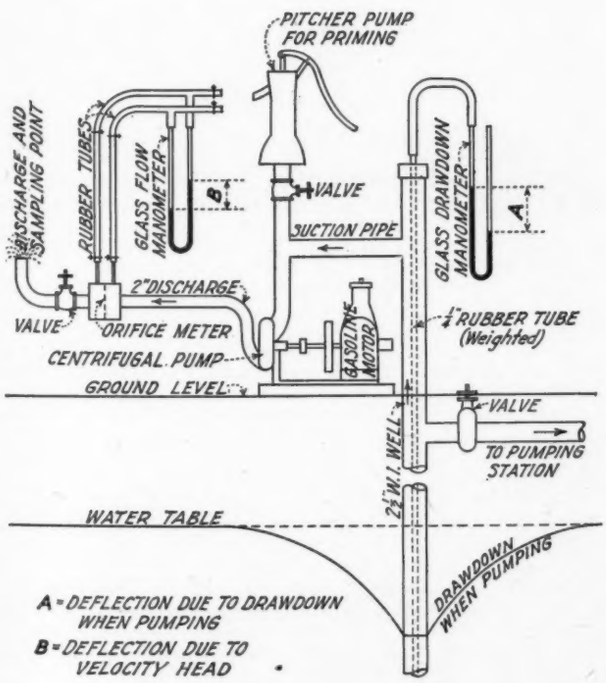
The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

Acknowledgment—The above paper was presented before the New England Water Works Association, at Providence, R. I., Sept. 19, 1935, and appeared in WATERWORKS & SEWAGE for December, 1935.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

INEXPENSIVE LABORATORY FLOCCER

By G. R. FRITH*

Chemical Engineer, Atlanta, Ga.

With the importance of flocculation being widely recognized and its use becoming more prevalent in water and sewage treatment plants where chemical coagulation is employed, a demand has arisen for a simple flocccer suitable for making a series of laboratory floccing tests simultaneously.

The accompanying pictures illustrate an adaptation of an easily made machine devised and used by the writer for the past five years in sewage work.

The usual hitch in making an electrically driven floccer is the difficulty of making the operating speed slow and variable. Any speed desirable in flocculation is easily obtained with the illustrated machine by merely turning on more or less water to the aspirator. The automobile windshield wiper, if in good condition, is very powerful and will operate as many jar agitator paddles in a row as desired.

An ordinary automobile windshield wiper with vacuum supplied by a laboratory aspirator or suction pump is the motive power. The other materials needed are a few 3/16-inch brazing rods, some sheet brass or other metal, a few brass or copper washers, and several two quart fruit jars, preferably square. Round jars may be used on this machine, due to the oscillating motion of the paddles, if square jars are not available. The wood frame may be built from packing cases if nothing better is at hand.

A crank, with about one inch offset, is first made for the windshield wiper and fastened on to the shaft either with solder or a threaded collar, depending on the type of wiper used. The brass rod is cut into appropriate lengths to allow for bending a crank on one end with the same offset as the driver; and to allow for the thickness of the wood cross piece with enough rod remaining to reach nearly to the bottom of the fruit jars when in floccing position. The rod may be bent in a small vise with a hammer. The wood cross piece which acts as a bearing for the paddle shafts is about 1 by 1½ inches in cross section and the holes are drilled through the 1½ inch way. The holes should be a good fit for the paddle shafts but not tight. It is important that the holes be properly spaced and drilled vertical, or there will be difficulty in lowering the paddles into the jars.

A washer is soldered on to each paddle shaft at each bend of the crank to act as support for the connecting rod and the paddle shaft respectively. The paddle shafts are then run through the bearing holes in the wood cross piece and another washer soldered to each snugly against the under the wood cross piece.

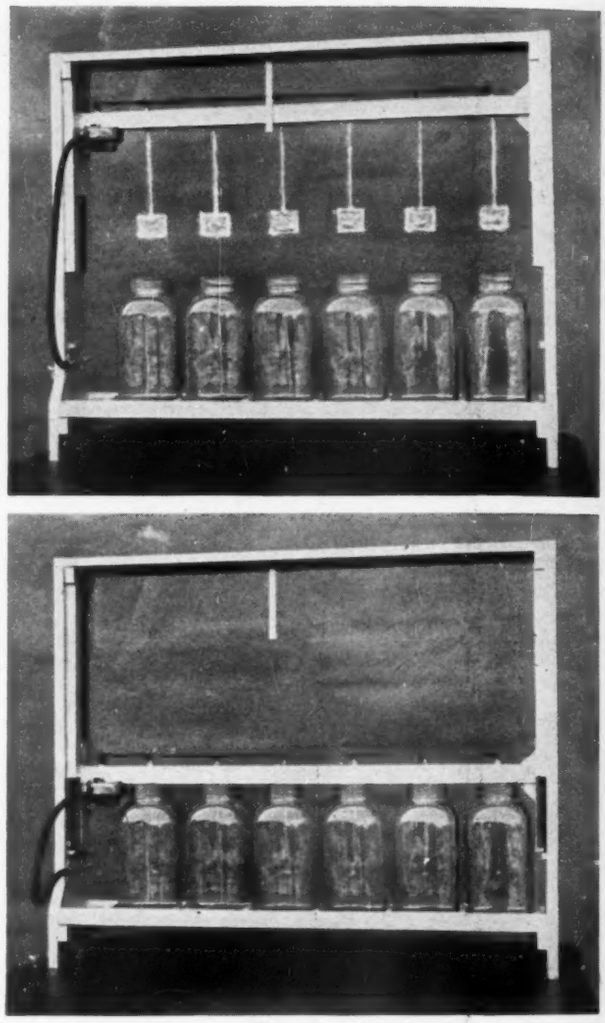
The connecting rod is made from a piece of ⅛-inch sheet brass ½ inch wide and of proper length for the desired number of jars. The holes are drilled on the same centers as those in the wood cross piece. It is not usually necessary to fasten the connecting rod in place, as its own weight should keep it on the cranks of the stirring rods.

The paddle blades consist of one piece of 1/16-inch sheet brass about 1½ inches wide and of a length that will enter the mouth of the fruit jar. The blades are soldered to the paddle shafts. This completes the mechanical part.

The wood frame is made to permit sliding the machine-head up (out of) or down into the jars. The jars are spaced properly on the base by tacking on thin strips of wood. The short piece of rubber hose makes a permanent connection from the windshield wiper to a piece of brass pipe across the side of the frame merely for convenience in attaching the aspirator hose at the back.

The strap hanging from the top of the frame is a piece of hack-saw blade heated and bent to form a spring catch for holding the machine-head above the jars when not in operation.

There has been some comment to the effect that the oscillating motion may break some floc particles in the immediate vicinity of the blades. This is probably true; but there is no flocculator built, large or small, which does not have this same defect. The relative movement betwen the water and the paddle blades at their point of contact is necessarily great in crder to keep the water in the more remote parts of the floccing jars in a proper swirling motion. Overcoming this defect, inherent in all flocculators, would require a much more expensive installation and the benefit to results would not be worth the difference in cost. It would be necessary to distribute a large paddle surface throughout the tank and move it at extremely slow speed.



Laboratory Floccer. Motive Power Is Windshield Wiper Operated by Laboratory Suction Pump on Faucet. What Appears to Be a Rod Connecting the Stirring Rod Is a Flat Strip of Brass Drilled with Holes

However, there is nothing to be gained by the above argument one way or another. If you need a laboratory floccer and have no money to spend for speed reducers and an electric motor, one may be made with 50 cents worth of brass and a windshield wiper. If you do not have access to a supply of brass stock, a satisfactory machine may be made in an hour, using pieces of tin can for paddle blades and stiff iron wire for paddle shafts and connecting rod. The slide and frame is a real convenience but not a necessity.

*Bureau of Sewers and Sewage Treatment, Atlanta, Ga.

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†

"To meter or not to meter?" That is the question.

Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Metered

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words municipally owned are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.)

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantage in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of such outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood etc., is done away with when the outside setting is used.

6. More accurate readings can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customers' side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at

*From WATER WORKS AND SEWERAGE.

†Field consultant, Virginia League of Municipalities.

both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia*

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes wherever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straight-edge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

*When this article was written the author was City Manager of Bluefield, Va.—Ed.

Meter Repair Practices*

Water meter castings are painted by spray gun equipment. The meter casting sets on a turntable which revolves slowly. The colors used are Bronze and Aluminum.

Air chambers have been installed on the influent side of all the meter testing machines. This eliminates water hammer caused by the quick opening and shutting valves, especially effective when testing large size meters.

The use of Monel metal baskets for dipping meter parts in Dearborn 134 solution has been much more economical than the use of cheaper baskets.

An electric drill held in place by a suitable clamp arrangement is used for cleaning meter parts. The drill is substituted for a rotary wire brush. This cleans meter parts in a hurry.

The uses of compressed air in a meter repair shop are many. This added convenience in meter shop repair work will speak for itself.

The use of a hand press similar to the press used on electric drills is a sure way of observing the fit of the disc in the chamber before the meter is put together. This eliminates the guess work connected with tight or ill-fitting discs.

An elevated container of gear lubricant is directly connected to a quick opening valve with string attachment. This gives positive control of the amount of lubricant added to the gear train chamber because it closes so quickly—thus eliminating the mess which generally accompanies the handling of gear lubricant.

*Courtesy, E. T. Cranch, mgr., New Rochelle (N. Y.) Water Co.

METER TESTING, REPAIR AND SELECTION

By CLEM. A. GALLAGHER

Superintendent of Services, Louisville Water Co., Louisville, Ky.

Recently while making a trip for the purpose of inspecting various meter shops throughout the country, one basic and sad truth struck me bluntly.

That sad truth is simply this: Despite all the progress made in the waterworks field in filtration, pumpage, construction and billing, yes, even in the meter field, a paradox still confronts us. The one sure-fire revenue producing instrument is seemingly neglected, if not ignored. Less, generally, is known about water meters than about any other essential waterworks mechanism. I am of the firm opinion that a definite, efficient, and consistent meter testing and repairing program is a vast asset to any Water Department or Water Company. The revenue accruing naturally from such a program will more than pay the initial expenditure for such a program in the first few years. The difference between 85 per cent and 100 per cent seems not so large arithmetically, but in just one service in one year's time it means many dollars and cents in any language.

Contrary to popular belief a meter testing and repair program is simple in itself. And the cost of such has been grossly exaggerated. By explaining simply, and somewhat in detail, the meter plan we have been working successfully and at reasonable cost in the Louisville Water Company, I hope to prove my contention that a definite, efficient, and concise meter testing and repair program is a vast and lasting asset to any water utility, irrespective of size. Further, that such a program can easily and reasonably be inaugurated and maintained.

The Four Phases of the Program

In such a definite program four phases comprising the composite must be considered and I shall treat of them in order. Meters must be exchanged, tested, repaired. Then, records must be kept of all these operations. It stands to reason that any system which would insure an unfailing and accurate record of a meter, from the time it left the ground until it was returned after testing and repair, would be the most desirable method from every standpoint.

This is our method: We have three men with small trucks exchanging meters daily and returning them to the shop. These men likewise take care of all meter complaints such as meters stopped, broken counters, leaks, etc. Normally each man and his helper will exchange about thirty-five meters a day. A card (here illustrated) has been devised to take care of all of the recording. This card is perforated midway and entwined with a wire at the top. The cards are numbered, and used and filed consecutively. On one side of the card at the top is a record for the meter reset after it has been repaired, tested and O. K.'d. Space is available for the make of meter, the serial number, size, the address set, the attachment number, the account number, the date set. It is signed by the man placing the meter back in the ground.

The lower half of the card on the same side has the record of the meter removed with make, serial number, size, reading, address removed from, attachment number, account number, date removed, reason for removal (exchange, frozen, out of order, etc.), and also space for the signature of the man removing the meter.

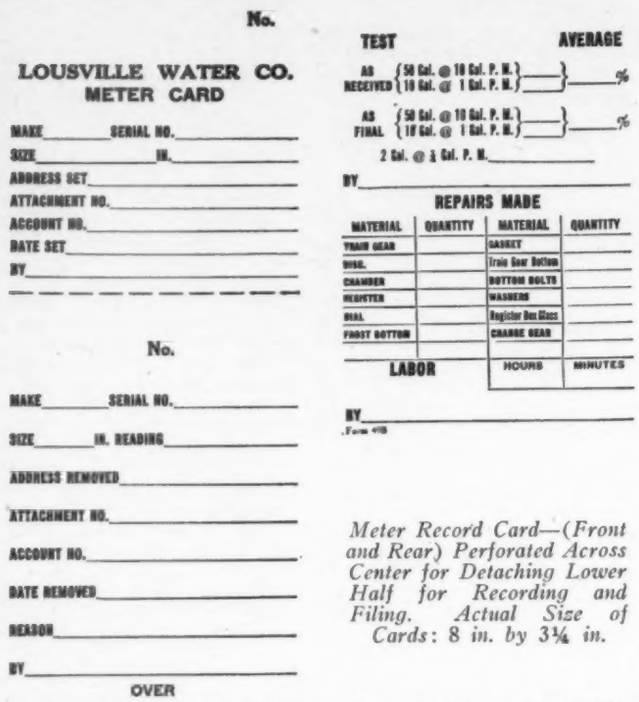
On the other side of the card the upper half is blank while the lower half contains a complete record of the meter test and repair. Each meter coming into the shop has this attached card wired to the casing so that this same card remains with that one meter from the time it leaves the ground at one location until it is returned to the ground in another place. This obviates the danger of lost cards and garbled records.

Each meter received in the shop is tested as received and tested, as final, after it has been repaired. Each meter is thoroughly cleaned and repaired irrespective of its first test average. Each 5/8-inch meter is tested with fifty gallons at ten gallons a minute and with ten gallons at one gallon a minute. The meter tester places both percentages on his card as well as the average of the two. The meter is then sent to the repair bench to be cleaned and repaired.

Thorough Shop Records

The lower half of this part of the card contains a list of the repairs made, parts replaced, and the time consumed in this

Meter Repair Shop, Louisville, Ky., Water Works



No.

LOUSVILLE WATER CO.
METER CARD

MAKE _____ SERIAL NO. _____
SIZE _____ IN. _____
ADDRESS SET _____
ATTACHMENT NO. _____
ACCOUNT NO. _____
DATE SET _____
BY _____

No.

MAKE _____ SERIAL NO. _____
SIZE _____ IN. READING _____
ADDRESS REMOVED _____
ATTACHMENT NO. _____
ACCOUNT NO. _____
DATE REMOVED _____
REASON _____
BY _____

OVER

TEST — AVERAGE

AS RECEIVED { 50 Gal. @ 10 Gal. P. M. / 10 Gal. @ 1 Gal. P. M. } ____ } ____ %

AS FINAL { 50 Gal. @ 10 Gal. P. M. / 10 Gal. @ 1 Gal. P. M. } ____ } ____ %

2 Gal. @ ½ Gal. P. M. _____

BY _____

REPAIRS MADE

MATERIAL	QUANTITY	MATERIAL	QUANTITY
TRAIN GEAR		GASKET	
DISC.		Train Gear Bottom	
CHAMBER		BOTTOM BOLTS	
REGISTER		WASHERS	
DIAL		Register Box Glass	
FROST BOTTOM		CHANGE GEAR	
LABOR		HOURS	MINUTES

BY _____

Form 415

Meter Record Card—(Front and Rear) Perforated Across Center for Detaching Lower Half for Recording and Filing. Actual Size of Cards: 8 in. by 3¼ in.

repair. The material is listed on the card with a corresponding space for the quantity of each part used and the bin number from which it was taken. As a consequence, each man while repairing a meter must put down just what new part, or parts, he used, how many parts were used and how long it took him to finish this one meter. The meter repair man then signs the card and the meter is returned to the testing table. It then goes through its final test of fifty gallons at ten gallons a minute; of ten gallons at one gallon a minute, and of two gallons at one-fourth gallon per minute as a final check. The averages are again noted and averaged and this part of the card is then signed by the chief meter tester. If the meter does not register within two per cent it is returned to the bench for a further overhauling. If it, however, registers accurately the card is then severed at the perforation marks and the lower half returned to the meter record office. This card contains, therefore, for the clerks in the meter record department, complete information in regard to this one particular meter including the removal of the same with all statistics, the testing of the same and the repairing of the same. The signature of each foreman definitely places responsibility for errors under each classification. The information from these cards is transcribed to the regular permanent meter cards and the shop tag cards are then filed, according to their test number, in a file to fit this card. This gives the department a test and repair file.

Our endurance test box in the basement is so constructed that it will hold twenty-five meters at one time. It is arranged in a series of two boxes and any meter of any series, either series, or both, can be removed at any time by means of valves without affecting the flow of water in the building. Our figures in many of these tests have been most startling, and seem to prove one thing very conclusively—that the A. W. W. A. specifications for ⅝ inch cold water meters are entirely too lenient. A well constructed water meter should register much better than 90 per cent on a one-fourth gallon per minute stream.

We recently made a meter under-registration survey. We brought into the shop at one time three hundred meters which had been in service five years or longer and tested them as received. The averages were startling inasmuch as the average percentage of inaccuracy on flows for all meters up to and including the one-fourth gallon per minute flow was far above standard requirements, for new meters.

It has been our endeavor in this entire meter program to aim first at thoroughness, but thoroughness through simplicity. We believe we have accomplished our goal and through the cycles described in this paper are able to test and repair water meters regularly, accurately, efficiently and economically. The cost of this program will be as nothing compared with the revenue pickup naturally consequent on such a program—not to mention the life added to the meters.

Any water utility, which neglects to maintain a definite regular meter test and repair program is neglecting what should be considered a water company's greatest asset. As the meters go—so goes your revenue. A water meter *can* be tested, repaired and kept in shape. Like anything else in life, so with water meters—the simplest and safest way is the best and the cheapest way.

The top half of the card remains, of course, on the meter until that meter is again taken out to be reset. Then in like manner the man resetting tthis meter or exchanging it for another fills out the information given above, disconnects the wire and card from the meter, signs the card and returns this reset information to the meter record department. We thus have a complete cycle for our exchange program and by the use of this simple card we have not only a method of double checking each step but also of definitely placing responsibility where it should be placed.

This exchange system, simple as it is, has worked out most successfully for us and should do so for others. The men exchanging meters take out each day just as many tested and repaired meters as they will exchange. This cycle keeps the shop free from meters piling up. At our present speed each of our 50,000 meters will be put through this process once every five years, although our tests (with our water and our meters) show that this period between tests for economy reasons should be lengthened appreciably.

Testing

Next we come to the testing of a water meter. As I have explained above, a meter is tested as received and again after repairs. The size stream for the test depends, of course, upon the size of the meter.

Our meter testing table can test ten ⅝, ¾ or 1 inch meters at a time. On an adjoining bench the larger meters, up to six inches, are tested one at a time. We have done away with the slower method of weighing for tests, and use only calibrated tanks and funnels. A hydraulic plunger keeps the meters in place. This test bench is so arranged that we can vary our stream anywhere from 225 gallons per minute down to 1/320 gallons a minute. The latter is accomplished by means of needle valves.

Recently we have standardized on the sweep-hand dials on all meters, for two very definite reasons. First of all it is much easier to detect a leak on any size meter if it is equipped with a sweep-hand dial, and secondly and even more important, it facilitates the testing of a meter in time saved and assures us that our registers are likewise accurate. We could not be sure of this by the use of test dials. Our meter tester and his helper average over one hundred ⅝ inch meters per day on standard tests. A cycle is likewise completed here, since in the morning meters are tested as final and in the afternoon a new lot is received. Thus the repair men on the bench, work each day on the meters tested as received the previous afternoon while the meter tester tests as final in the morning the meters repaired the previous day.

It is noteworthy that our records show that less than one percent of the total number of meters repaired have been unfit after repair, and have to be returned to the bench. The promiscuous use of change gears is undesirable and we try to get away from it as fully as possible.

Repairing

The next step in our meter routine is our repair bench. Five men work on this bench and each man has his own set of tools, his own sink with running hot and cold water, his own brushes and a hose with a stop-valve carrying compressed air of about seven to ten pounds pressure. This air is simply piped from our garage and reduced in the meter shop by means of a reducing valve. We have found that this compressed air at this pressure is most useful and practical for testing out the running smoothness of a meter as well as ejecting particles which may be holding back the best performance of a meter. It likewise does away with the necessity of the men placing their mouths on the outlet or inlet to a meter.

The meter bench is made of wood and covered with heavy galvanized iron. Above each man is an electric reflector which evenly lights up his place of work just where he needs it most. Each meter is placed in a separate pan to do away with the loss or mixing up of parts.

Our manner of cleaning a meter is simply the old fashioned but effective soap and water method. We deprecate the use of acid on any meter, or parts thereof, unless it is absolutely necessary. We have found that under our own water conditions the encrustation can be satisfactorily and more safely removed by good old hot water, soap, and elbow grease. We do no machining or reboring because, generally, replacement is cheaper and safer from every angle. Above the repair benches are marked and lettered compartments for the various parts of any

size or make of meter. This is part of our permanent running inventory system. Each closed bin contains a different part and each bin is numbered. When the men need any new part for any meter they must mark on their ticket the number of such parts used as well as the bin number from which it was taken. A regular inventory clerk can thus keep, from these cards, a daily record of just what parts were used and how many of each part remains in stock. He has a standard minimum of each part that should be kept in stock. He can daily or on a moment's notice notify the department head just what parts are needed and how many of each, and they are then requisitioned and ordered. Again this inventory system, though simplicity itself, affords an easy check on costs, new parts required, etc.

Each man averages between fifteen and twenty meters a day, completely cleaned and repaired. The average cost, not including overhead, runs about fifty cents a meter for tests and repairs. We use about fifty new discs a month. Bottom bolts and gaskets most often need replacement. A meter is scrapped only after it is completely a liability. We have returned to service meters, after overhauling and cleaning, which have been in the ground forty years and more. One man at another bench takes care of the registers, setting back to zero, lubrication, etc. We solder the counters and thus avoid ruining the gears by running counters back speedily with a motor driven disc. After cleaning, the registers of all meters are then dipped in hot oil and drained. This oil is fine, and not too thick for frigid weather. The meter shop is kept clean and each man knows just what he must clean up before he leaves. The work has been divided. The floor is waxed and a heavy, linked rubber carpet stretches all along the repair and test benches. On Saturday of each week larger meters, from one inch to six inch, are tested and repaired. Of course this work is slower and more tedious than that on 5/8 inch meters. A healthy spirit of competition, a desire to keep the meter shop clean and a pride in repair average, can work wonders if engendered and encouraged.

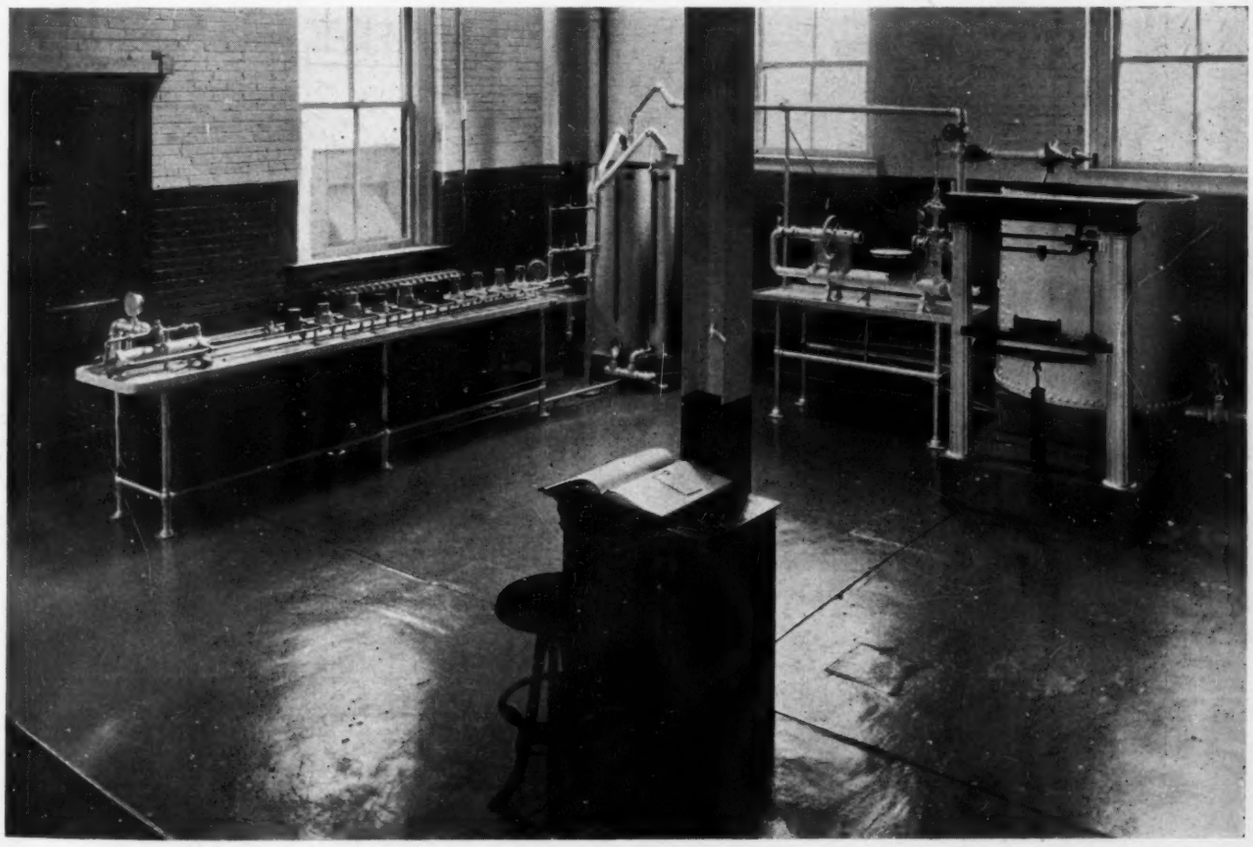
Meter Recording Office

On the same floor is our enclosed meter record office. The head of the Meter Department and clerks keep all records of all meters. We keep two cards on each meter—one according to make and serial number and one according to the book and page number in the meter readers' books. All information—address, make, size, serial number, purchase date and price, sets and resets, tests and repairs, are kept on these cards. Any information concerning any meter in service at any address, any meter in the stock room, or in the shop, is available at all times. The city is divided into districts, lettered alphabetically, and a reference from card to meter books gives all information concerning reading, leaks, etc. The two sections of the numbered cards are filed separately after the information thereon has been transcribed to the other set of cards. These test and repair cards give the final shop information on any particular meter. This system of checks and balances assures accuracy, permanency, and simplicity. All necessary information is always at hand and any meter can be traced from the moment we receive it until we scrap it. We are at present about 75 per cent metered and have in the ground approximately 50,000 meters.

Selecting Meters

When purchasing a water meter three things must be taken into consideration, namely, accuracy, endurance, and interchangeability. It was our desire to find out just what meters would be most dependable under Louisville water conditions and with this idea in mind we have been conducting a series of tests with new stock meters. Ten of each make are tested at a time. The new meters are tested, as received, on flows of ten gallons a minute, one gallon a minute, one-fourth gallon a minute and one-twelfth gallon a minute. These same ten meters are then placed in an endurance test box in the basement and the water used in our building allowed to run through them until they register an average of five hundred thousand (500,000) gallons. We can vary this flow in the building as desired.

They are then taken back to the shop and retested exactly as above. The figures are then averaged, with emphasis on the average percentage of inaccuracy, and blue prints are made of the records for permanent filing Next, these meters are taken apart and thir parts interchanged. They are run then for approximately one hundred thousand gallons and retested again according to the former specifications. Finally they can be run on an absolute endurance test, which of course takes time, until one or more meters in any series breaks down. Faulty meters are taken apart and the cause of such break down investigated.



Testing Benches and Equipment, Meter Shop, Louisville, Ky., Water Works

SELECTING THE RIGHT METER*

By ROGER W. ESTY**

Superintendent, Danvers Water Works, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

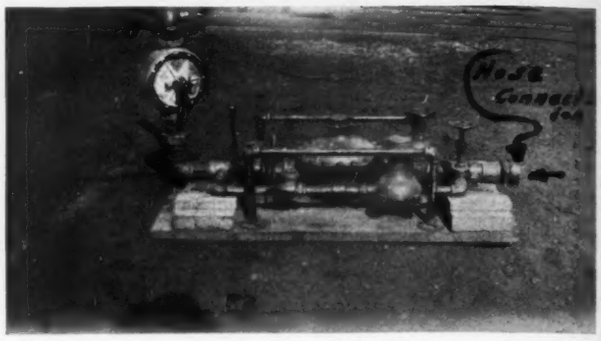
In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, Sept., 1934.

**The author has the distinction of being now (1936) President of N.E.W.W.A.

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

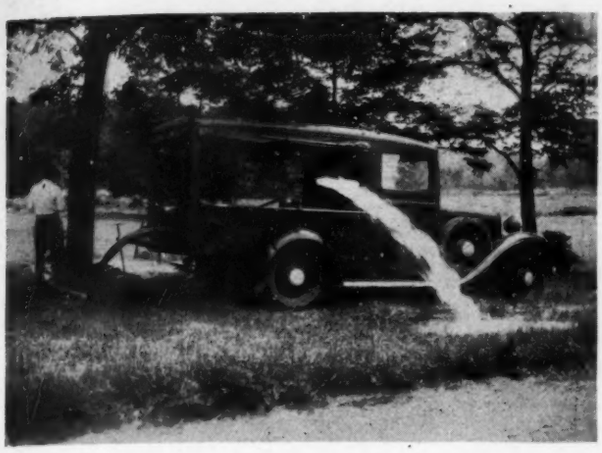
We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch



Portable Meter Testing Outfit on Service Wagon. Connection Is Made by Fire Hose to Meters Tested

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

Experience in Sterilizing New Mains

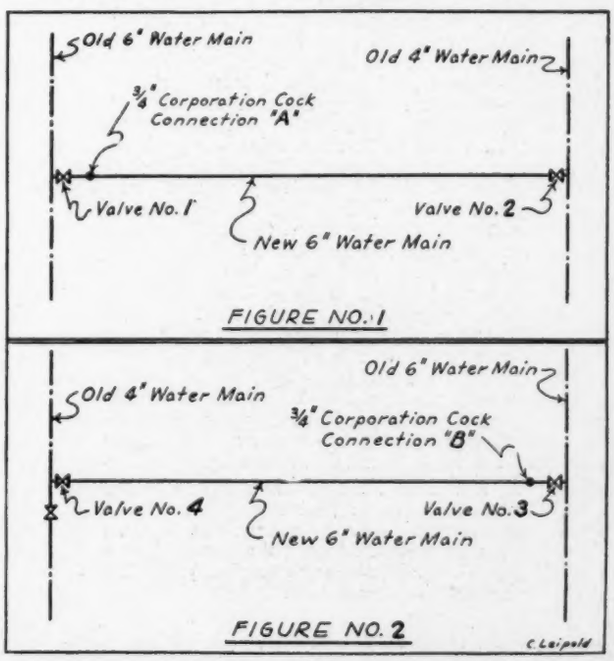
By CARL LEIPOLD

Superintendent of Filtration, Winnetka, Ill.

It was shown by tests made at the time of sterilizing a new pipe line that it is very essential that the water added to the pipe will distribute the applied "H T H" (calcium hypochlorite) uniformly through all parts of the new pipe.

On completion of a new pipe line (Fig. 1) about thirty grams (a heaping handful) of "H T H," representing a treatment of 100 lbs. chlorine per million gallons of water, was applied through a paper funnel placed in the neck of the corporation cock at connection "A" and the pipe was filled with water through valve No. 1. Residual chlorine tests made of the water samples collected from connection "A" after all the air was removed and the pipe was full of water, showed only .10 to .20 p.p.m. of free chlorine. After a chlorine contact period of 3 hours, valve No. 2 was opened and the new pipe line was flushed through connection "A." Residual chlorine tests made of the water samples collected from connection "A" showed a gradual increase of free chlorine and after 30 minutes of flushing the test showed a deep red color. These results indicated that on filling the pipe line, the largest portion of the disinfectant had been carried to the far end of the pipe line near valve No. 2, leaving no chlorine for sterilization at the near end of the pipe line where introduced.

On completion of another new pipe line (Fig. 2) the same sterilizing procedures were carried out as described above with the exception that a different method of filling the pipe line with water was employed. This pipe line was partially filled with water through valve No. 3 and then completely filled with water through valve No. 4. Flushing the pipe line through connection "B" from valve No. 4 was done until the residual chlorine test of the water sample showed a deep red color. It was then closed off. After a chlorine contact period of two hours, valve No. 4 was again opened and the new pipe line was flushed through connection "B." The residual chlorine tests made of the water samples collected from connection "B" showed a gradual decrease of free chlorine and after 30 minutes of flushing the test showed no free chlorine. These results indicated that the "H T H" had been uniformly mixed throughout the pipe line by proper control of the valves.



Illustrating an Effective (Fig. 2) and an Ineffective (Fig. 1) Method of Sterilizing Water Mains

BATTERY METERS—THEIR INSTALLATION AND PERFORMANCE

By C. M. McCORD

General Superintendent, Water Department, Memphis, Tenn.

In view of what appears to be possible advantages to be had by using a battery of three 2-inch disc meters, instead of a single compound or turbine meter, an investigation was made as to the most practical and satisfactory method of installing or piping them. To begin with, standard fittings were used to build up the two manifolds. The center fitting in each case was a cross with nipples and ells on both sides of the crosses. Between these made up manifolds, the three meter legs were built up, each leg including a 2-inch disc meter with flange couplings ahead and back of the meter, and 2-inch gate valves between the flanges and the manifolds. It was found to be a difficult job to run these three short legs in between the two fixed manifolds. Each leg must make up the same length and the alignment must be practically perfect. While it is not an impossible job, it is one that is slow and difficult. After this set-up was made it was apparent that the meter vault should be large enough to include the manifolds so that they could be inspected and repaired if necessary.

To simplify the installation, both as to fittings and labor, and to provide manifolds that could be built into the vault walls,

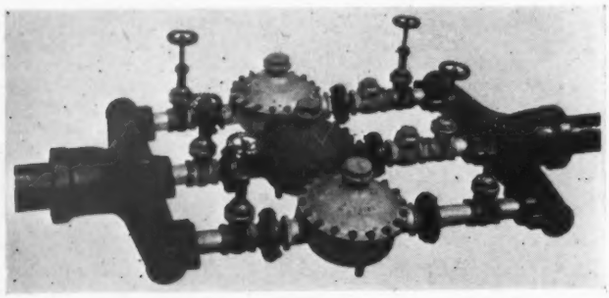


Fig. 1.—Battery Meter Arrangement Designed for Memphis, Tenn. Note special C. I. manifolds and check valve arrangement causing all minor flows to register through one meter.

two cast iron manifolds were made, each having a 4 inch bell inlet and three 2 inch bell outlets properly spaced for the connecting meter legs. The advantages of these cast manifolds are, first: Being cast iron, it is possible to incorporate them in walls of the vault thereby reducing the size of the vault; second: It is not necessary to set them an exact distance apart, nor is it necessary that they be in exact alignment; third: The meter legs, including meter, flanges, check valve and valves are made up at the shop and should they vary as much as an inch in length, they can be readily installed. After the manifolds have been set a measured distance apart, to install the meter leg, one of the flange couplings is taken loose, dividing the leg into two sections. One section is then placed into the bell of one manifold and the second section is placed into the bell of the other manifold. The flange joint is remade, the leg adjusted to position laterally and caulked in place with a small amount of lead wool. After the three legs have been installed in this manner, then the bell joints are poured and caulked in the usual manner. By cutting a light running thread on the 2 inch nipples that are caulked, this prevents them blowing out when a meter is removed and also makes it possible to screw this nipple into and out of the lead joint should it become necessary.

In this test installation, check valves were placed in two meter legs for the purpose of protecting these two meters from hot water and to direct all very small flows to one meter only, rather than have it divide between the three. The accompanying photograph (Fig. 1) shows quite clearly the installation as made by using cast iron manifolds.

Testing for Accuracy

After developing a practical and easy method of making the installation, it was then decided that tests would be run to find

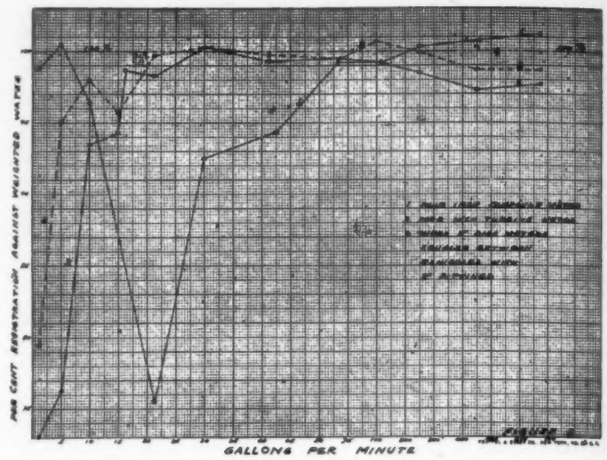


Fig. 2.—Compound of Accuracy of Meter Registration. (Battery Meters vs. Compound vs. Turbine Meters.)
Curve 1—Four inch compound meter.
Curve 2—Four inch turbine meter.
Curve 3—Three, 2 inch disc meters coupled in parallel battery.

out what *our* meters would do under *our* observation. Meters were taken from our shop that were pronounced ready for service. Back of the battery meters pictured, was placed a 4 inch compound meter and back of this a 4 inch turbine meter. This was a series arrangement, water passing through the three measuring arrangements and into a large scale tank, thus making it possible to readily compare the registration of each device against dead weight. Figure 2 shows the results of these tests, rate of flow being plotted on the X axis and percentage of registration on the Y axis. These curves have not been ironed out in anyway and the small circles are the actual results plotted. They may not be the curves that some might expect, but, nevertheless, they represent what happened when *we* tested *our* meters.

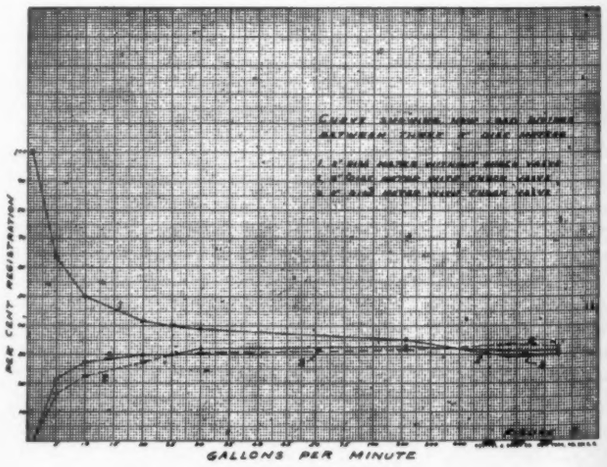


Fig. 3.—Division of Load Between Three 2-inch Meters in Battery. (Note that check valves throw all flow under 5 g.p.m. to the one meter without a check.)
Curve 1—Two in. disc meter without check valve.
Curves 2 and 3—Two in. disc meters with check valves.

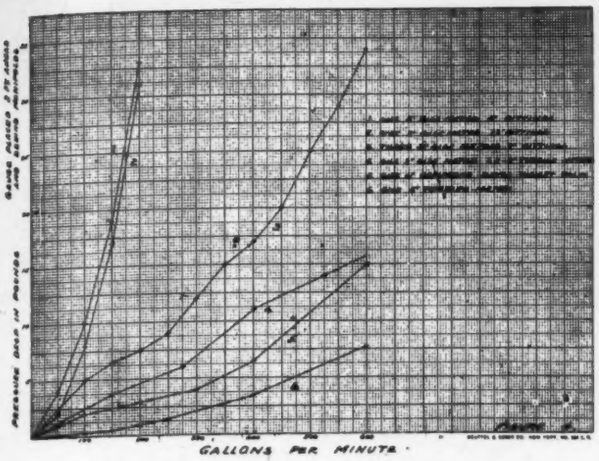


Fig. 4.—Curves Indicating Comparison of Pressure Drop Through Battery Meters vs. Other Types. (Note: Where pressure loss can not be tolerated turbine and compound type meters must be selected at the expense of low flow inaccuracies.)

Curve 1—One 2 in. disc meter with 2 in. fittings.
Curve 2—One 2 in. disc meter with 2½ in. fittings.
Curve 3—Three 2 in. disc meters with 2 in. fittings.
Curve 4—One 2 in. disc meter and two 2 in. turbine meters.
Curve 5—One 4 in. compound meter—weight valve.
Curve 6—One 4 in. turbine meter.

An investigation was then made to determine how the load would divide between the three 2 inch disc meters that made up the battery. Figure 3 plainly shows the result of this test. The number one meter, without check valve, took the small flow entirely and as the flow was increased it shared the load in an increasing amount with the other meters until the flow was about evenly divided. It was also established that on removing the two check valves and operating all three meters without these valves, that one meter took the very small flows. With the checks out, first one meter and then another would register, but with check valves in two legs, the small flow was always registered by the meter without the check.

The last phase of the investigation covered the drop in pressure. This was measured in the case of the battery meters about 2 ft. ahead of and behind the manifolds, and about the same distance ahead and behind the two larger meters. The results obtained are shown in Figure 4, which is self explanatory. After these tests were made, we piped one of the disc meter legs with 2½ inch nipples and valves, and from the figure it will be seen that the drop in pressure was not helped greatly. An examination of this data indicates clearly that different conditions and circumstances demand different methods of metering. In some cases, it may prove necessary to sacrifice small flow registration in favor of increased pressure. In other cases, the small flows can be picked up at the expense of loss in pressure at the larger flows. On these considerations the most desirable arrangement can be selected and the service metered accordingly.

CHECKING WATER HAMMER*

When the water flowing through a pipe is stopped very suddenly there is rise in pressure in the pipe line that may at times amount, roughly, to 50 times the velocity in feet per second at which the water is moving at the instant.

The best cure for water hammer is a slow-closing valve. The next best cure is to provide an air chamber located as close as possible to the valve. If kept fully charged, an air chamber is considered to be of sufficient size when its capacity is one per cent of the pipe line it serve to cushion. Means of renewing the air cushion must be provided for.

Required Volume of Air Chamber

The size, that is, the volume, of an air chamber depends upon a number of factors of which the principal ones are:

The length and size of pipe that the air chamber serves.

The rate of flow of water through this pipe.

The pressure in the air chamber immediately preceding the stopping of the flow, and the pressure due to the stopping of the flow, and,

The nature of the action that puts the air chamber into service—whether it be instantaneous, or rapid, or prolonged.

The following treatment is based upon the first three factors. With reference to the fourth factor—it is the more or less instantaneous stopping of the flow that makes necessary the use of an air chamber. Hence, we are virtually assuming the condition of rapid closing. By this method a volume of air chamber is determined such that the energy of the moving water is absorbed between prescribed limits of pressure in the air chamber.

We have the expression,

$V = L \times P \times R^2$, in which

V is the internal volume of the air chamber in cubic inches,

L is the value from Table 59 for the size and length of pipe that the air chamber serves,

P is the value from Table 60 for the flowing pressure and the assumed maximum pressure, both in the air chamber, and

R^2 is the square of the rate of flow through the pipe in gallons per minute immediately before the stopping of flow.

Note—The flowing pressure can be determined approximately by deducting from the static pressure at the air chamber the loss of pressure in the run of piping (for which the size of an air chamber is being found) under the assumed rate of flow.

Determine the size of an air chamber for a ¾-inch branch, 20 feet long, carrying 10 gallons per minute, based on pressures of 20 pounds per square inch flowing, and 60 pounds per square inch maximum.

Substituting,

$V = 0.042 \times 1.6 \times 10^2 = 6.7$ cubic inches.

Having determined the volume of the air chamber, it becomes necessary to fix the proportions—whether to make it of relatively small diameter and correspondingly long, or short and "dumpy." If made of ¾-inch pipe, length would be 6.7/0.53, or 12.6 inches. Sectional area of ¾-inch pipe is 0.53 square inch from Table 61.

TABLE 59
Values of L

Length of Run, Feet	Size of Pipe, Iron Pipe Size ½	¾	1	1¼	1½	2	2½	3	4
10.....	.037	.021	.013	.0074	.0055	.0033	.0023	.0015	.0009
20.....	.074	.042	.026	.015	.011	.0066	.0045	.0030	.0017
30.....	.111	.063	.039	.022	.016	.010	.0068	.0045	.0026
40.....	.148	.084	.052	.030	.022	.013	.0091	.0060	.0035
50.....	.185	.105	.065	.037	.027	.017	.011	.0075	.0044
60.....	.222	.126	.078	.044	.033	.020	.014	.0090	.0052
80.....	.296	.168	.104	.059	.044	.026	.018	.012	.0070
100.....	.370	.210	.130	.074	.055	.033	.023	.015	.0087
125.....	.462	.262	.162	.093	.068	.041	.028	.019	.011
150.....	.555	.315	.195	.111	.082	.050	.034	.023	.013
200.....	.740	.420	.260	.148	.109	.066	.045	.030	.017
250.....	.924	.524	.324	.185	.136	.082	.057	.037	.023

Note that for each size of pipe value of L is proportional to length of run.

TABLE 60
Values of P

Maximum Pressure, Lb. Sq. In.	Flowing Pressure, Lb. Sq. In. 15	20	25	30	35	40	50	60	80	100
20..	42.									
25..	12.	56.								
30..	6.0	16.	72.							
35..	3 8	7.8	20.	90.						
40..	2.6	4.8	9.8	25.	110.					
50..	1.6	2.5	4.2	7.3	14.	36.				
60..	1.1	1.6	2.5	3.8	6.0	10.	49.			
80..	0.67	0.92	1.3	1.7	2.4	3.3	6.9	18.		
100..	0.48	0.63	0.82	1.1	1.4	1.8	3.0	5.4	27.	
120..	0.37	0.47	0.60	0.75	0.93	1.2	1.8	2.8	8.0	39.

TABLE 61
Sectional Area of Pipe

Size of Pipe Iron Pipe Size	Area of Internal Cross-Section of Pipe Sq. In.
½	0.30
¾	0.53
1	0.86
1¼	1.50
1½	2.04
2	3.36
2½	4.78
3	7.39
4	12.7

(The above article should be useful in meter shop practice and otherwise, where quick closing valves must be employed.—*Ed.*)

*From "Water Supply in Buildings," by Alex. W. Moseley, Mass. Inst. of Technology, 1935.

PRIMARY ELEMENTS FOR SEWAGE AND WATER WORKS METERS

By L. D. CARLYON, M.E.*

Cleveland, Ohio

In modern sewage plants and water works, metering equipment is now recognized for the important part it plays in obtaining efficient control and operation.

Regardless of type, large meters and registering devices depend upon the so-called "Venturi" principle for their operation. This consists of producing a differential pressure which varies in a definite and known relation to the rate of flow. The differential pressure is mechanically converted into terms of weight or volume and is so indicated and recorded by registering equipment. The actual registers themselves are constructed to provide various combinations of indicating, recording, and totalizing features.

There are three commonly used devices, which can be inserted in fluid lines to produce the desired differential pressure. These are the Venturi tube, the flow nozzle, and the thin plate orifice. Each provides a reduction of the area through which the flow takes place, thereby causing an increase in velocity at this point with a corresponding localized reduction in pressure. The result is a differential in pressure between two areas of the Venturi tube, or on either side of the flow nozzle or orifice inserted in the pipe. Figure 4 illustrates the head differentials created by an orifice insert.

For a given installation the primary element is designed and constructed so that when the maximum rate of flow occurs, a definite maximum head differential will be produced. This varies from a water differential of less than 10 inches to one of more than 200 inches, dependent upon the fluid to be measured, the static pressure, the maximum capacity and the type of register.

Although any one of the three primary elements (Venturi, flow nozzle, or plate orifice) can normally be used, there will usually be one of the three which is best suited to meet the existing requirements. The selection is determined by a number of factors. These factors are to be dealt with in this article, with a view of better acquainting engineers, superintendents or operators with the more important considerations in selection of metering devices. It is hoped that some of the confusion concerning these devices which exists in the minds of some will be cleared away by the following discussion.

Fundamental Comparisons

The Venturi Tube

The Venturi tube has been used for years in connection with projects of the hydraulic and sanitary engineer. As illustrated in Fig. 1, it is designed with a short cylindrical section at the inlet end of the tube, which is cast smooth inside. The high pressure connection is made at this point into the piezometer ring (Fig. 1, Section AA).

*Mechanical Engineer, Bailey Meter Co.

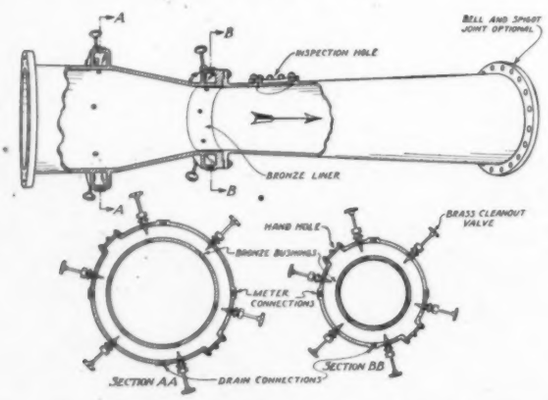


Fig. 1—Venturi Tube. (Handholes and Cleanout Valves Are Used Only for Measurement of Screened Sewage or Sewage Sludges)

Fig. 2—Venturi Throat Section for a 56-Inch Line, Constructed of Cast Iron with a Machined Bronze Liner

Following the inlet section is an entrance cone of about 21 degrees total angle, which leads to the short cylindrical throat section where the low pressure connection to the meter is made through another piezometer ring. At the throat the tube is flanged, and has a handhole which permits inspection of the throat and piezometer holes, as well as accurate measurement of the throat diameter. An exit cone, known as the diffuser, follows the throat and has a total angle of approximately 5 degrees. This ends in a flange for connecting the tube to the pipe line flange.

In certain cases due to objection to the laying length of the long Venturi tube or possibly for reasons of cost, a tube referred to as a "short Venturi" is used. It differs from the long tube primarily in that the angle of the exit cone is much greater (normally 13 to 15 degrees total angle), thus making the overall length much less than a long tube of corresponding diameter which is justified on the grounds that a smaller head loss is created.

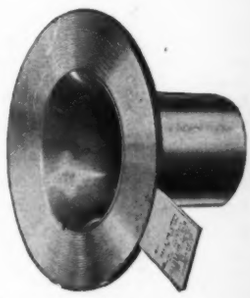


Fig. 3—Flow Nozzle

The majority of Venturi tubes are fabricated of cast iron and are provided with brass or bronze liners in the throat which are machined smooth within close tolerances. Small tubes of from 1 to 2 inches diameter are often made of brass or bronze throughout and the entire length of the internal surface may be completely machined all over. Very large ones have been constructed of concrete or steel plate with a cast iron throat section having a machined bronze liner, such as shown in Fig. 2.

Flow Nozzle

In many respects the flow nozzle (Fig. 3) may be considered to be a simplified Venturi tube. The entrance consists of a gradual curve of approximately one-quarter ellipse which leads the fluid smoothly into a short cylindrical throat section. Thus the discharge jet will have no contraction and will be the same diameter as the throat itself.

Installation of the flow nozzle is made by inserting it between a pair of pipe flanges. The high pressure upstream connection is usually made by tapping the pipe line approximately 1 pipe diameter back of these flanges, and the low pressure connection is made on the line at a point just opposite the throat section of the nozzle. For the measurement of water, air, sewage or

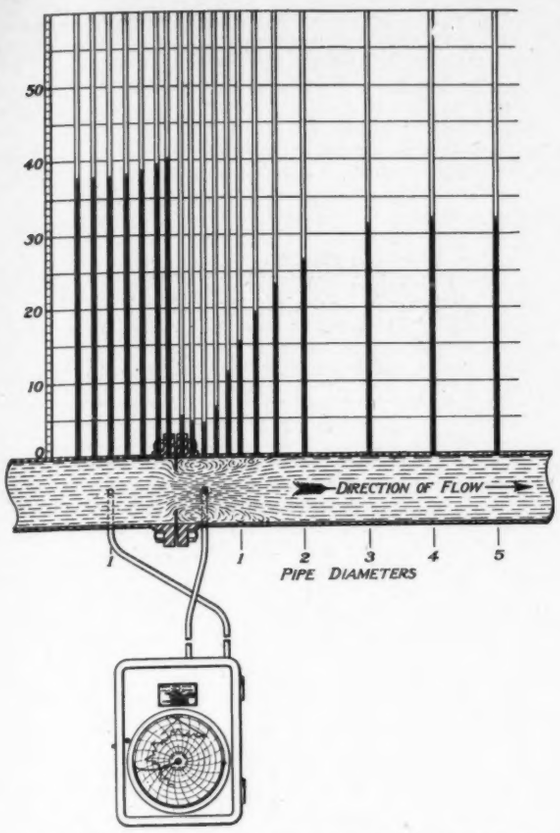


Fig. 4—Diagram of "Stream Lines" in a Fluid Flowing Through a Circular Concentric Orifice in a Pipe, Pressures Existing at Various Distances from the Orifice

sludge, flow nozzles are usually fabricated of bronze, the inside being very accurately machined.

Thin Plate Orifice

The thin plate, or sharp edged orifice, shown in Fig. 4 has been widely used for many years to measure the flow of fluids. In its simplest and most familiar form, the orifice is merely a hole in a flat plate which is clamped between flanges in the pipe line. It may be of 1/16 inch thickness or more, depending upon its diameter, and can be made of nickel, monel metal, steel or other suitable material. Flow meter literature abounds with results of thousands of experiments proving conclusively that the orifice operates on the same basic principles as does the Venturi tube and flow nozzle.

Referring to Fig. 4 it will be noted that there is a well-defined Vena Contracta (plane of greatest contraction) on the down-stream side of the orifice plate, just as is observed when the stream from a sharp edged orifice discharges into the open air. The pressure on the outlet side of the orifice varies along the length of the pipe with the velosity of the stream itself, the observed pressure being least (differential the greatest) when the connection is exactly opposite the Vena Contracta.

The location of the Vena Contracta remains constant regardless of the rate of flow for any one installation. It assumes a slightly different position, however, with different ratios of orifice diameter to inside pipe diameter. For a given ration, its relative position is independent of pipe size. The high pressure upstream tap is made at approximately one pipe diameter back of the orifice, and the low pressure tap is made exactly opposite the Vena Contracta. Some manufacturers recommend that the taps be close to and on either side of the orifice plate; in this case it is necessary to obtain the orifice plate and the flanges as an integral assembly.

Factors to Consider

Before a metering element is specified or selected for a given project, six factors must be taken into consideration if the most suitable arrangement is to be secured; namely (1) initial cost, (2) installation, (3) accuracy, (4) reliability, (5) pressure loss, (6) capacity change.

The above factors may not appear in their order of importance, for the item which is of primary importance for any one application will vary with conditions peculiar to that application.

1. Initial Cost

The initial cost (purchase price) of the primary element may vary within wide limits. Figure 5 illustrates the approximate relationship between present-day prices of long Venturi tubes, short tubes, bronze flow nozzles, and thin plate orifices. It will be noted that for a given size, the price decreases in the order named. Without question the orifice has a decided advantage with respect to initial cost, being approximately one-ninth that of a long Venturi tube of corresponding size.

In the larger sizes, say above 24 inches, it is also possible to obtain orifices at prices from 20 to 25 per cent lower than those shown, by specifying a steel orifice plate having a nickel insert. This insert has the orifice hole machined in it and thus the more expensive metal is used only where it is essential.

Very large Venturi tubes become cumbersome and expensive. On this account large tubes are frequently constructed of steel plate or concrete at its location and only the throat section is purchased from the meter manufacturer.

2. Installation

From the standpoint of ease of installation, the orifice or flow nozzle would be selected in preference to a Venturi tube. They need merely be inserted between a pair of flanges in the pipe line, but considerable care must be taken to center the element properly, to make the pressure connections at the correct locations, and to see that there are no protrusions left on the inside of the pipe line as the result of making the taps.

The Venturi tube being relatively larger and much heavier, more time and labor is required in the installation. If the pipe line is an existing one, it will be necessary to remove one or more sections of pipe and to provide filler pieces of the correct length so that the tube can be made a part of the line. On a new project, however, in comparing the cost of installing a Venturi tube a credit representing the cost of a section of straight pipe of the same length, which otherwise would be required if a flow nozzle or orifice were used, should be considered.

Since the pressure taps are an integral part of the tube, these can be assumed to be correctly placed.

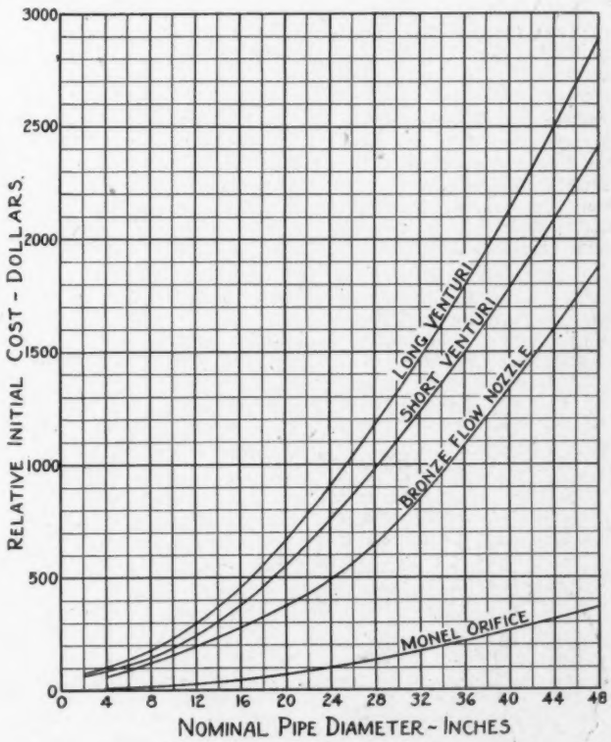


Fig. 5—Curves Showing the Approximate Purchase Prices (at Factory) of Various Types of Primary Elements. (The Curves for the Venturi Tubes Are Based on Weights Suitable for Use with Class A, B, and C Cast-Iron Pipe, and Do Not Include Handholes or Cleanout Valves Shown in Fig. 1)

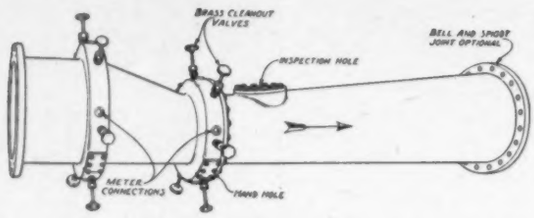


Fig. 6—Eccentric Type Venturi Tube for Sewage or Sewage Sludges

3. Accuracy

When installed under suitable conditions, the three primary elements are very nearly equal when compared on the basis of accuracy obtainable; namely, within 1 per cent of 100—plus or minus. Due to small inaccuracies introduced by the register mechanism, however, manufacturers normally extend a conservative guarantee that the reading will be within 2 per cent of 100 plus or minus. In actual practice the accuracy always falls well within the limits of the guarantee.

In order to insure accurate metering, all primary elements require a certain length of straight pipe preceding the location. For the Venturi tube, 5 to 10 pipe diameters are usually adequate. For the flow nozzle or orifice types this requirement is between 8 and 20 pipe diameters, depending on the ratio of orifice diameter to inside pipe diameter, and on the piping layout. Sometimes these requirements cannot be met due to the piping layout. It is under such conditions that the short Venturi tube occasionally proves most suitable because it is from 30 to 45 per cent shorter than the long tube of like diameter.

In order to preclude high readings on the registering device, the primary element should not be installed where the air or liquid flow is of a rapidly pulsating nature. Such a condition may be caused by water or sewage reciprocating pumps and by certain types of air blowers. It is sometimes possible to eliminate pulsations or dampen them materially but where pulsating flow is likely to be a problem this factor should be called to the meter manufacturers' attention; whereupon, specific recommendations will be made.

4. Reliability

It is essential that the primary element retain its accuracy after installation and that it also provide continuity of satisfactory service.

Screened sewages and sewage sludges present the greatest problem of measurement because of solid matter or gas which they contain. For this service the piezometer rings of the Venturi tube are equipped with cleanout valves (Fig. 1) which facilitate routine cleaning operations to maintain the openings free from obstructions. Connections should be made at top and bottom of each ring for venting accumulating gas or draining sediment. Handholes in each ring make the interior accessible.

At low velocities the throat section of the Venturi tube may act as a dam causing foreign material to settle on the bottom of the inlet cone and, thereby, affecting the accuracy. A condition of this kind can be largely avoided by the use of an eccentric Venturi tube (Fig. 6) which differs from the ordinary tube only in the eccentric shape of the converging and the exit cones. The fact that the bottom of the tube lies in one horizontal plane makes it easier for solid materials to be swept through the tube.

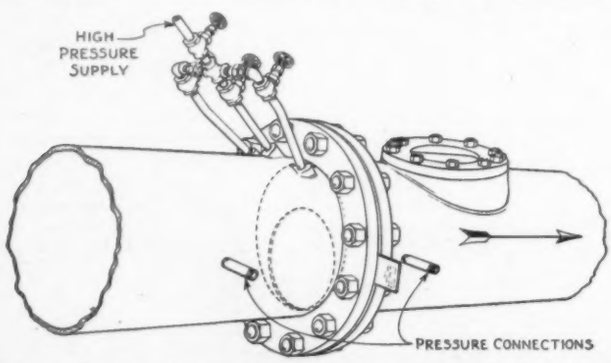


Fig. 7—Eccentric Type Orifice Installed in a Sewage Main, Illustrating an Arrangement for Washing Collected Materials Off the Face of the Orifice Plate

An installation of an orifice in a sewage line is illustrated in Fig. 7. Here also the eccentric type is of particular advantage in that solid materials pass through without obstruction. While there is even less chance of materials settling on the sharp edged opening than in the throat of a Venturi tube, there is a greater possibility of material collecting on the entrance side of the plate. For this reason it is desirable to provide a high pressure water supply into the pipe line (Fig. 7), for periodically washing off the face of the plate.

A common method for the prevention of plugged taps, and to keep the meter connections clean and free of deposits is to introduce a continuous trickle of clean water through the connecting pressure lines to create a slow current into the main pipe line.

Unless there is some especial factor involved, the flow nozzle should be avoided in metering sewage, because there is a tendency for materials to deposit in the throat section and to build up at the entrance. However, it has proved satisfactory where a

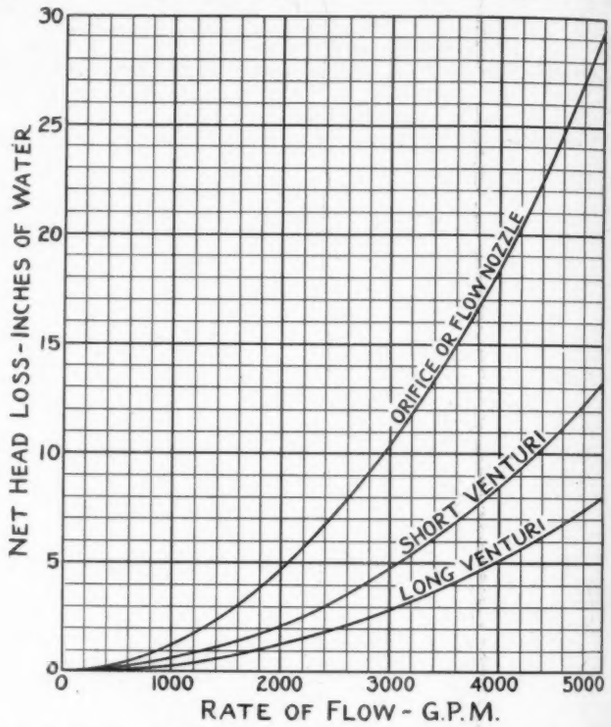


Fig. 8—Curves Showing the Net Differential Head Loss Created by Different Types of Primary Elements, Designed for a Maximum Differential of 53 Inches of Water, at a Maximum Capacity of 5,000 g.p.m., as Applied to a 20-Inch Water Main

means has been provided for flushing out the entrance and throat frequently.

Measurement of unscreened sewage should be avoided, except where there is no alternative, as for example when one community has its sewage treated in the plant of another municipality. The large heavy solids may cause greater wear and erosion on the primary element, and in the case of an orifice installation, there is the added danger of an object striking the plate with sufficient force to cause distortion.

Comparatively little attention is required for primary elements in air lines or fresh water mains, and all three elements will function indefinitely with practically no attention.

5. Pressure Loss

The differential head created by any of the three primary elements represents only a localized drop in pressure, most of which is restored upon resumption of normal flow a short distance following the primary element as is pictured in Fig. 4. It is important to hold head losses to a minimum, especially when capacities are large and available head is at a premium, or where pumping is involved and power requirements must be considered.

With the long Venturi tube, the pressure loss at any rate of flow is only approximately 15 per cent of the actual differential head produced by the element at that rate of flow, whereas with the short tube the loss is approximately 25 per cent.

The percentage loss created by orifices or flow nozzles depends

upon the ratio of the throat diameter to the internal pipe diameter—the smaller the throat or orifice the greater the percentage loss. When designed for identical conditions of capacity, etc., the percentage loss will be virtually the same for both the orifice and the flow nozzle.

As a typical example, assume that a water meter operating on a maximum differential head of 53 inches of water is to be applied to a 20-inch main and to have a maximum capacity of 5,000 g.p.m. The loss of head created at maximum flow by the various elements as shown by the curve in Fig. 8 would be:

Long Venturi, 7.95 in. water (.15 × 53).
Short Venturi, 13.25 in. water (.25 × 53).
Orifice or Flow Nozzle, 29.15 in. water (.55 × 53).

With a flow of 2,500 gallons per minute (½ of maximum) the losses produced would be only ¼ of these values, because the differential head varies proportionately to the square of the rate of flow.

Although the curves of Fig. 8 apply only to the specific example, it can readily be seen that conditions exist where, by use of a Venturi tube, the reduced cost of pumping over a short period of time will more than offset the higher initial cost of the Venturi tube.

5. Capacity Change

An existing meter installation may at some time require an increase in maximum capacity to meet the requirements of increasing quantities of fluid handled by the system. This may be accomplished in three ways—either by providing a new primary element, by modifying the old one to handle the larger capacity, or by increasing to the required extent the maximum differential head with which the register functions.

With the Venturi tube, the first two methods are costly, particularly in the larger size and therefore the register differential is usually increased. It should be borne in mind, however, that with this method, at rates of flow exceeding the original maximum capacity the pressure loss increases as the square of the flow.

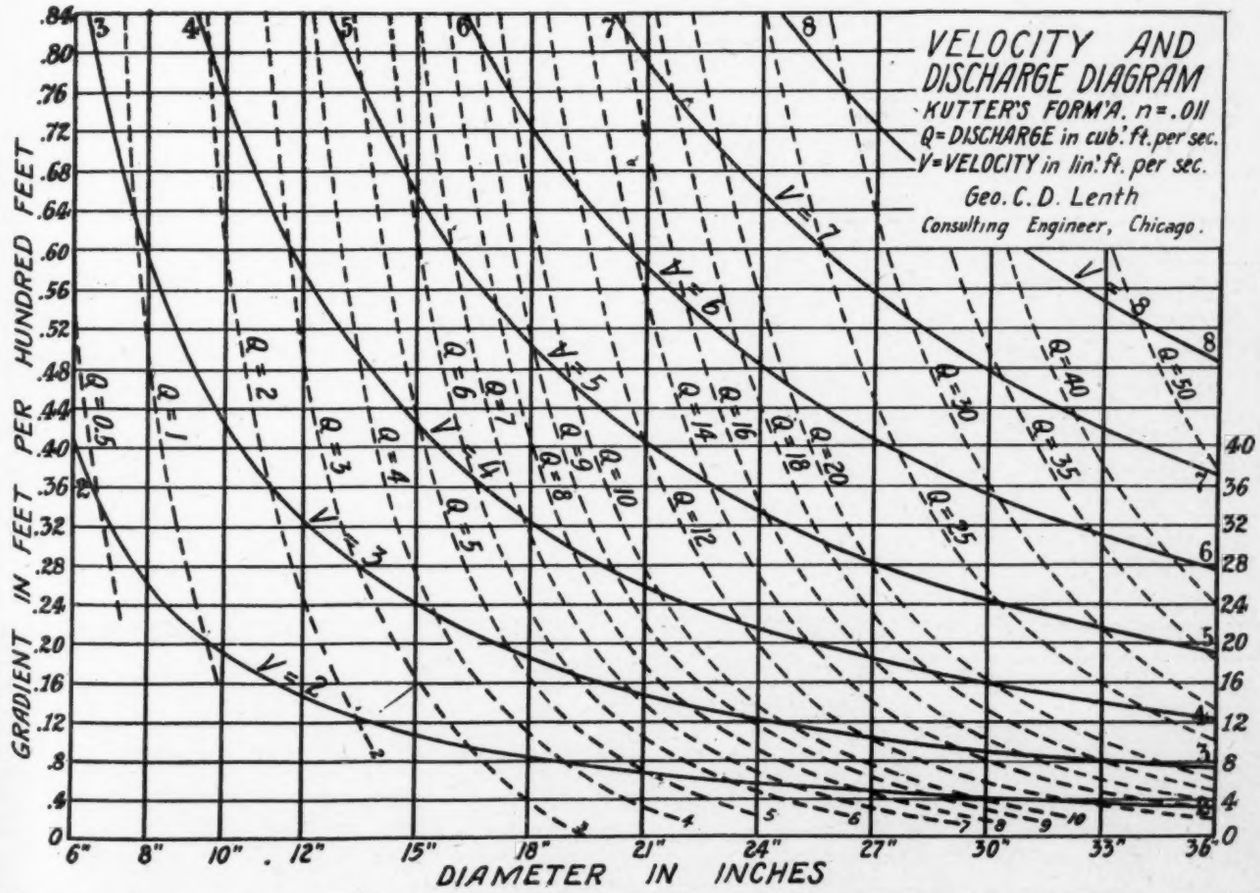
When an orifice or flow nozzle constitutes the primary element, a new one can usually be installed at reasonable cost. Since such a change necessitates a larger orifice the pressure loss will be lower than for the original installation, notwithstanding the increased flows handled. This naturally cannot be accomplished in cases where the primary element originally installed is already near the greatest ratio for which it can be designed. It is necessary then to increase the differential head of the register and suffer the head loss entailed or else to provide a duplicate installation on a parallel twin line.

Knowledge of the principles described and intelligent consideration of the six factors outlined above will aid materially in obtaining primary elements which are most suitable for the particular project from the standpoint of both satisfactory operation and cost.

Final decisions can be made only when complete details and figures are available pertinent to the specific problems under consideration. Therefore, it is important to supply meter manufacturers with as complete data as possible concerning each contemplated meter installation, such as the type of fluid, maximum capacity, pipe diameter, pressure, and a dimensioned sketch of the piping layout.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

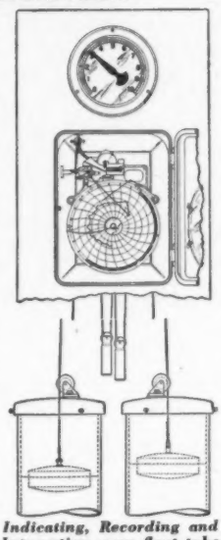
BOSTON NEW YORK BUFFALO PITTSBURGH ERIE CINCINNATI CHICAGO MILWAUKEE
ST. PAUL KANSAS CITY HOUSTON DENVER SAN FRANCISCO
BAILEY METER COMPANY LTD., Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

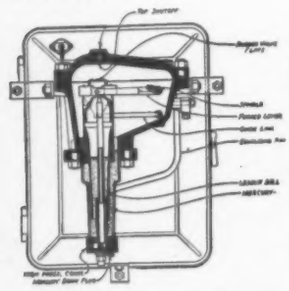
Open Float Tube Type—This register accurately measures the flow of sewage, sludge, dirty water or other liquids, using a Venturi tube, flow nozzle or orifice as the primary element. The external appearance of this indicating, recording and integrating register is shown in the installation photograph below. All parts are of stainless steel, copper, aluminum or other materials especially selected because of their ability to withstand the corrosive action of sewage, gas and sludge.

A high degree of accuracy is insured by a large float and a relatively large float motion applied through differential gearing and a cam to operate the register in direct proportion to the rate of flow.



Indicating, Recording and Integrating open float tube type Register.

Ledoux Bell Type—This register, operated by a mercury sealed Ledoux Bell is particularly well adapted to the measurement of sewage sludge or water under pressure or where wide changes in hydraulic gradient are encountered. When applied to the measurement of sewage or sludge, settling chambers are used and a supply of fresh water is introduced so that a constant flow exists from the register to the Venturi tube. This is, of course, unnecessary when the meter is applied to clean water measurement.

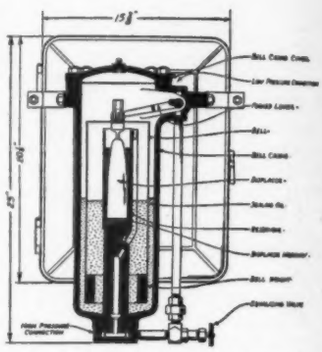


Section through flow mechanism of Ledoux Bell type Register.

In the water works field this register is particularly well adapted for use on discharge lines from centrifugal pumps, on gravity mains, on branch lines and distribution systems, and in filtration plants to measure raw water, clear water and wash water.

Suitable equipment can be furnished when it is desired to totalize the flow through several lines.

Air Meters—These meters measure air flow in main lines and in individual lines to aeration tanks. It is desirable to meter both air and sewage to individual aeration tanks in order that they may be properly proportioned for best results in consideration of such factors as quality of raw sewage, detention, tank agitation and economical use of air.



Section through flow mechanism of Air Meter

This register differs from the Ledoux Bell type, previously described, only in the flow mechanism which in this case is designed to operate on a maximum differential of 8" of water. The motion of the oil sealed bell is transferred to the uniformly graduated chart by means of a forked lever, spindle and recording pen.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

SLUDGE BLANKET DETECTOR AND TURBIDIMETER

By DON E. BLOODGOOD

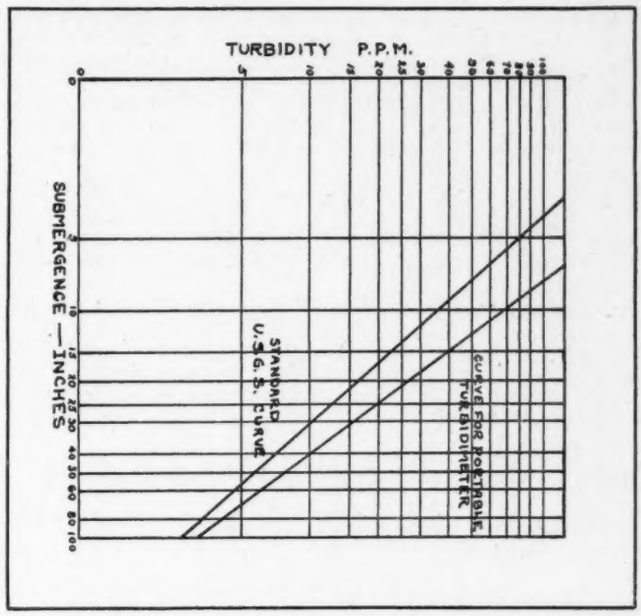
Engineer, Sanitation Plant, Indianapolis. Ind.

To a sewage plant operator, the appearance of the effluent is the best indication of the effectiveness of the treatment process. But to convey to the superintendent an accurate description of the appearance, in writing, is difficult. A superintendent should know each morning the hourly condition of his plant during his absence. He also wants his operators to be able to tell him how one day's effluent compares with that of any other day.

To supply this information in the most concise, yet explicit form, an instrument has been constructed at the Indianapolis Sewage Treatment Works which can be used as a portable turbidimeter and a sludge blanket detector. It consists of an 1¼ inch I.D., 0.065 wall, 2 FH aluminum tube 68 inches long with a sleeved brass collar on the bottom into which the brass moisture proof lamp case screws. There are four ports in the cap which admit water but exclude all outside light. The glass disk is held against a rubber gasket making a water tight joint. In the 1/32 inch metal disk there is cut a ¾ inch cross of 0.012 inch opening with the center closed off by a piece of metal not larger than 3/32 inches in diameter to blank out the bright spot caused by the bulb filament. The light reflector is painted with aluminum paint. The operation of the lamp is identical with the ordinary two cell flashlight except for the self-operating mercury switch. This mercury switch is in the base cap of the lamp case and is constructed in a case of sealing wax. The sealing wax was first run into the base cap and sloped to a small depression in the center. A short piece of No. 24 platinum wire was set on each of opposite sides of the depression with the ends about ⅛th of an inch apart. One wire is grounded to the base cap and the other is connected to a copper plate, making a connection with the battery through the coil spring. Only a very small drop of mercury is needed in the switch. After the mercury is placed, a heavy paper disk is set over the top of the mercury pocket and the cap is filled with sealing wax.

In use, the instrument is submerged to a point at which the cross disappears and then the scale on the side of the tube is read by looking in to the six-sided mirror of the float, in one plane of which the figures will show. The mirrors are set at a 45° angle with water proof china cement in sycamore or any other tough light wood.

The portable turbidimeter was calibrated by getting the submergence in effluents of known turbidity. This data when plotted on logarithmic paper gave a curve somewhat different than did the data of the standard U.S.G.S. turbidity table, as can be seen by the accompanying graph. The scale for any turbidimeter constructed could be obtained from the graph of the calibration data



Graph for Converting Submergence Into Trubidity Reading

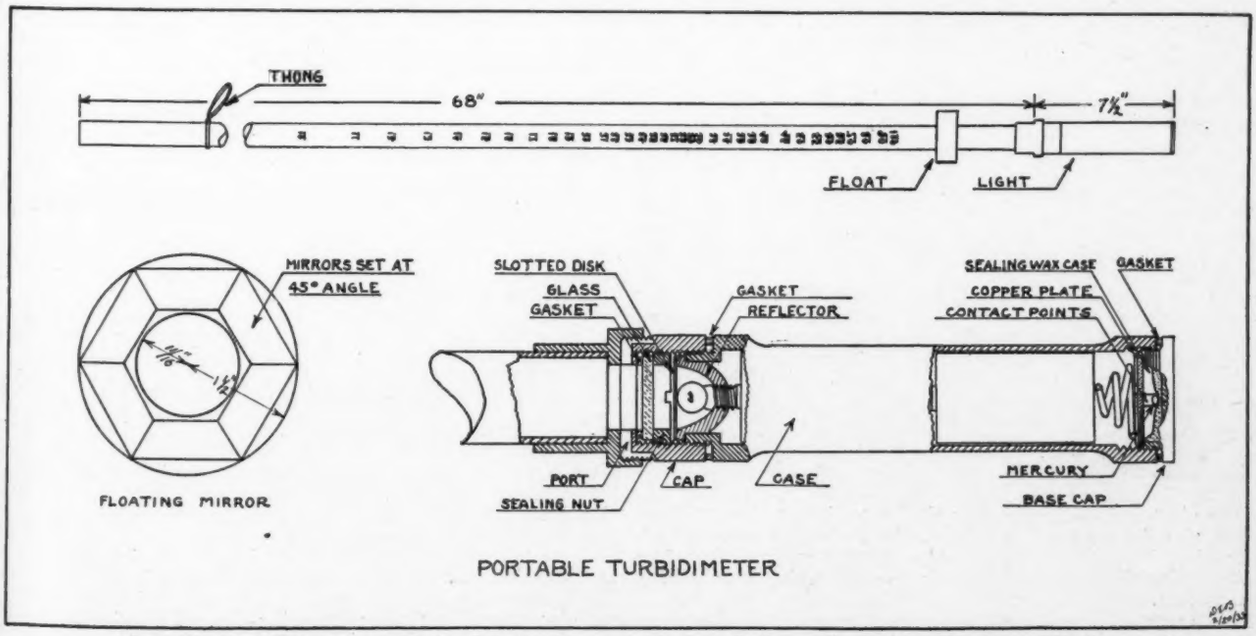
or it could be calculated by developing a formula for the particular curve, similar to the formula of the standard curve:

$$\log y = -1.106598 \log X + 2.6570$$

in which y= p.p.m. of turbidity and X = submergence in inches. The curve for the portable turbidimeter herein described is:

$$\log y = -1.35652 \log X + 3.2085$$

The shortcomings of the portable turbidimeter are appreciated. The turbidity increases at lower levels of the basin so that the readings obtained may not describe the nature of the actual effluent and yet be indicative of plant operation. At Indianapolis, however, the information obtained through the use of the portable immersion turbidimeter has been very helpful in connection with plant operation.



Portable Turbidimeter and Sludge Blanket Detector Used at Indianapolis Sewage Treatment Works

REDUCING THE COST OF CHLORINATING

By C. H. VIVIAN

Phillipsburg, N. J.

By introducing chlorine into sewage by recirculating a portion of the effluent to operate chlorinators, instead of using expensive tap water for the purpose, three New Jersey communities have materially reduced their water bills—and thereby the overall cost of chlorination. This departure from conventional practice should prove particularly beneficial to those towns which do not own their water supply systems, or where there is a shortage of water.

Ocean Grove, Deal, and Long Branch, N. J., are the places where the new method was first successfully applied, and they adopted it in the order named. All three are seashore resorts and all buy their water from a privately owned Water Company.*

The chlorine is introduced by conventional methods, being fed from cylinders by standard mechanical chlorinators. In two of the three communities effluent is used to operate the injectors whereas tap water is still used to feed the trays of the vacuum type machines. In the other, sewage effluent is employed even for this service.

The Use of Effluent First Tried at Ocean Grove

The only additional equipment that had to be provided was a suitable small pump and the piping required for delivery of some of the effluent, under pressure, to the chlorinators. A. J. Mount, operator of the Ocean Grove plant, who conceived the idea of using effluent for this purpose, selected for this service an Ingersoll-Rand "Motorpump," and thereafter the other two cities selected similar units when they adopted the scheme This pump consists of a motor and pump built integral and with a common shaft, which makes for compactness and reduces the number of bearings to a minimum.

The Ocean Grove plant handles an average of about 400,000 gallons of sewage daily, although, as previously mentioned, the quantity shows wide variations. The chlorination chamber is in the form of a series of connected parallel concrete channels and are located underground beneath a section of the boardwalk along the water front. The period of detention of sewage in these channels is from 20 to 30 minutes.

At a point just short of the weir over which the effluent discharges, a portion of it is taken out for operating the chlorinators. As the pump is housed 15 feet higher, this imposes a suction lift of that distance, but the pump performs satisfactorily under this condition. The effluent is three feet deep in the contact chamber and the suction line is submerged to within about eight inches of the bottom.

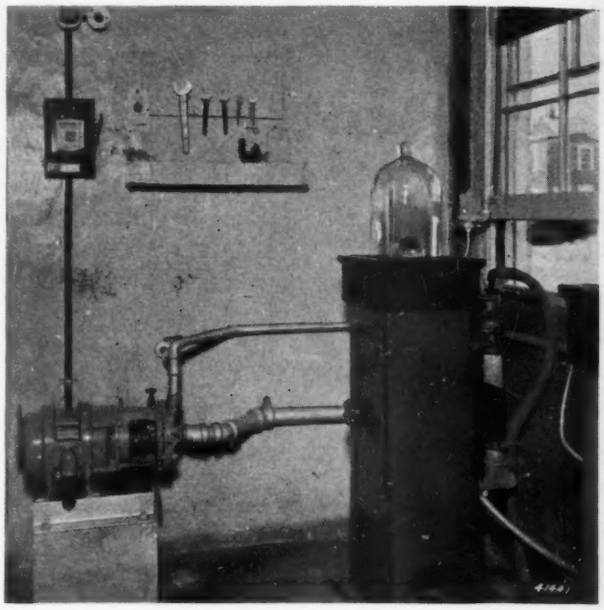
The pump is rated at 20 g.p.m. against a head of 100 feet. It is driven by a General Electric 1½-hp. (3,500 r.p.m.) motor.

The water rate at Ocean Grove is on a siding scale, the range being from 30 cents per 100 cu. ft. down to 20 cents until 65,000 cu. ft. have been used, after which the same scale is repeated. During the five months that chlorination was practiced, the plant used an average of 22,700 gallons of water a day. The cost was $772. By using effluent for all purposes around the plant, except supplying the chlorinator tray, the water bill was reduced to $9 during the next five-month period of chlorination. Current for operating the pump cost $105. As the installed cost of the pump was $160, it saved its first cost and operating cost nearly twice over during the first season of use. Maintenance and repairs totaled less than $2 during the five months, even though the unit was in service almost constantly.

The Deal Installation

The plant at Deal is generally similar to that at Ocean Grove. Here, also the treatment structures are all located underground. The plant handles up to 800,000 or 900,000 gallons of sewage daily during the summer season, the average being around 600,000 gallons.

*There have been others to do so since.—Ed.



At Long Branch, N. J.—Ingersoll-Rand Motor Pump Connected to Wallace & Tiernan Chlorinators. If the Pump Stops Nothing Happens Because the Chlorinator Automatically Stops the Flow of Chlorine Gas

Chlorine is dosed by one of two Wallace & Tiernan vacuum type machines. The effluent suction line to the chlorination "motor pump" consists of 200 feet of 2-inch line and the pump suction is under a head of 18 inches. The pump is of the same type as that used at Ocean Grove, but is slightly larger in size. Its present capacity is 20 g.p.m. against a head of 100 feet and it is driven by a General Electric 2-hp. (3,490 r.p.m.) motor.

Before the new arrangement was adopted, the plant used about $625 worth of water during the 5-month chlorination period.

The Long Branch Installation

The Long Branch plant is larger than the other two described and differs from them also in that it is operated by a private company, the Long Branch Sewer Company.

Incoming sewage is registered by a Simplex meter and goes to a wet well, from which it is pumped by any one or more of four Fairbanks-Morse vertically disposed electric-driven units. In gallons per minute, these pumps have capacities of 400, 700, 1,000 and 1,000 respectively. A 14-inch line extends from the wet well to the two sedimentation tanks of concrete construction, each being 50 feet square and 14 feet deep and having a capacity of 350,000 gallons. They are fitted with Dorr traction-type clarifiers. At 4-hour intervals, the sludge is pumped to adjacent digestion tanks, from which the gases escape to atmosphere through a 75-foot hollow steel flagpole.

Two Wallace & Tiernan vacuum type chlorinators are installed, one being used at a time. The effluent recirculating pump is a Cameron 1-RV-2 rated at 40 g.p.m. against a 98-foot head. It is driven by a G.E. 2-hp. (3,490 r.p.m.) motor. The water bill has been cut at least 75 per cent by the change over to the use of plant effluent instead of fresh water.

From the above experiences it is evident that the cost of sewage chlorination can be materially reduced in many instances by the practice of utilizing plant effluent in place of the community water supply for operating the chlorination equipment. Furthermore, the scheme has been proven entirely practical.

SEWAGE TREATMENT BY MODERN CHEMICAL METHODS*

By LINN H. ENSLOW

Editor of WATER WORKS AND SEWERAGE, *New York, N. Y.*

There has been a revival of chemical treatment of sewage involving modernized chemical-mechanical methods. The past two years (1933 and 1934) might be considered as a period of "watchful waiting" for developments and an evaluation of accomplishments of chemical processes on the part of sanitary engineers. Today (1935) there are 50 or more American plants completed, under construction, or definitely planned, in which chemical precipitation alone or in combination with biological processes is being, or will be, employed. In addition, there are not less than 14 such plants proposed, 12 to employ chemical treatment alone and 2 to use it for assisting biological processes.

In view of these developments since the completion of the first of the modern plants—that at Dearborn, Mich.—it seems proper to review the reasons for the revival of chemical processes, to weigh their advantages and shortcomings as employed today, and to look into their probable future.

An analysis of the reasons for the revival of chemical processes in sewage treatment shows that the outstanding one is that they fill the gap between sedimentation on the one hand, and the activated sludge process and the sprinkling filter on the other. Sedimentation, while simple and inexpensive, removes a comparatively low percentage of the solids and organic content of the sewage. The activated sludge process, which is highly efficient in this regard, is complex and expensive; and the sprinkling filter entails a large capital investment and considerable land area and is frequently attended by odor and insect nuisances.

The need for a process capable of producing an effluent of pleasing appearance similar to that from a properly functioning activated sludge plant, with perhaps a somewhat less complete removal of organic matter but at a lower cost, was and is the desideratum. The need has been felt for a controllable process less disastrously affected by sudden discharges of industrial waste than is the activated sludge process. The availability of modern mechanical equipment; of chemical feeding devices; of varied, improved, and less costly coagulants; and of more precise and better understood methods of control have, collectively, placed chemical treatment on a far more inviting basis than it was in the last century, when it was found less attractive on practical grounds and also more expensive than the biological processes of that day.

Added to these reasons for revived interest in chemical treatment is another and important consideration—its desirability, due to low first cost for plant and equipment, for seasonal use. Although the operating cost may be higher while it is employed, the average over-all cost is less than that of providing biological treatment for similar seasonal use.

Cost and Flexibility Are Primary Assets

Possibly the chief point in favor of chemical treatment is the fact that plants to provide it are less costly to build than plants for biological treatment and less expensive to operate, considering that the application of chemicals may be discontinued for long, short, or seasonal periods, as determined by the condition of the water course into which the effluent is discharged. During periods of 6 to 8 hr. of each day, usually the sewage reaching treatment plants needs nothing more than sedimentation to produce an effluent that will be acceptable under the most exacting standards. It is apparent therefore that a small investment in structures, equipment, and stocks of chemicals, and ability to make treatment more or less complete on short notice, as desired, both appeal strongly to the sewage treatment economist.

Flexibility of purification efficiencies attainable through mechanical-chemical methods is also alluring. If by ordinary sedimentation a degree of purification of 35 to 40 per cent is attainable, then by adding chlorination to further reduce the oxygen demand, a degree of purification up to 55 or 60 per cent —possibly 65 per cent—can be secured. Further, by a combination of coagulation and sedimentation a degree between 65 and 75 per cent can be attained with certainty. Proceeding still further, a degree of purification as high as 80 or 85 per cent can be had, when a combination of chemical precipitation and chlorination is employed.

Laboratory Tests Fail to Give True Picture

An important distinction should be made between the apparent purification efficiencies of chemical processes, as measured in laboratory bottles, for the 5-day oxygen demand test, and the actual comparative benefits to be noted in stream improvement. For example, as noted by actual observation, the 35 per cent degree of purification indicated by laboratory findings as being creditable to sedimentation is in truth far more valuable in obtaining stream improvement than this figure would indicate. It must be given a far greater weight in the final analysis than the next increment of 35 per cent of purification, by whatever method it is secured, which involves the removal of non-settleable and slowly settleable materials, which also form sludge and scum. This fact becomes evident when it is considered that the most important elements in creating nuisances in streams are the sludge and slime-producing substances, which can be removed almost completely by simple sedimentation and which when not removed result in cumulative and localized bottom and marginal conditions.

Settled sewages also carry colloidal and pseudo-colloidal solids, which are deposited on contact surfaces in streams to produce unsightly and cumulative slime masses mixed with filamentous biological growths. In saline or brackish waters the pseudo-colloids become "salted out" and precipitate to produce sludge deposits. It should be noted that chemical precipitation leaves nothing in the effluent capable of producing cumulative effects from after-precipitation or colloid adsorption by contact surfaces in the water course. Therefore when the oxygen-demand test reveals an added improvement of 35 per cent as the result of chemical precipitation, there is justification for considering the true effect, which may be realized in terms of actual stream improvement, to be greater than the laboratory picture would indicate. Weighing performances thus, and considering the markedly improved appearance of the effluents attained by chemical precipitation, the true potential advantages of such treatment become evident.

Processes that are capable of coping with industrial wastes, either alone or when added to domestic sewage, are daily assuming greater importance. Authorities are being increasingly confronted with the problem of disposal of such wastes through the municipal sewer systems. Chemicals toxic to the activated sludge process and non-uniform organic loadings, which overtax and upset biological processes, require a new type of treatment planning for the future. To demand that industry keep its wastes out of municipal sewers or apply partial treatment to them before they are discharged into the sewers may be theoretically advisable, but in actual practice it seems difficult of attainment. It would appear therefore that a possible practical solution to this problem is offered by chemical treatment—either alone or preliminary to secondary biological processes, if not continuously, then during the hours of heaviest industrial loading.

Controllability in handling sewage of variable quality and volume is among the advantages of chemical processes. Although the control of such processes is not as simple as some would have us believe, nevertheless deficiencies in treatment are more readily and quickly ascertained and adjusted, to procure effective results, than is possible with biological processes that have suffered an upset.

Choice of Coagulant and Process

For coagulation there are still available, as of old, the simple ferrous sulfate and lime. To efficiently employ this combination on most sewages, appreciable aeration is required as well as a pH value of 8.4 and higher. Among the modern coagulants there is ferric chloride, available in liquid, lump, or anhydrous form; the new anhydrous ferric sulfates; and chlorinated (oxidized) ferrous sulfate, known as "chlorinated copperas," which is produced as used by merging the chlorinator discharge solution with the copperas solution as it leaves the dry-feed machines. Another method of procuring ferrous or ferric

*Excerpts from paper read before the American Society of Civil Engineers, January 17, 1935, and printed in the April, 1935, issue of "Civil Engineering."

chloride employs a tower filled with scrap iron, through which chlorine water flows slowly upward. The ferrous chloride may be used as such or may be converted to ferric chloride by further chlorination of the tower effluent. Chlorinated ferrous sulfate for the present appears to be the most economical ferric coagulant. In the final analysis, selection of the coagulant should hinge on the question of what materials or process will yield the greatest weight of ferric iron at the least expense. In chemical precipitation, all ferric salts are about equally effective on the basis of the iron involved. However, this is not so with sludge dewatering on the acid side of neutrality. In this case ferric chloride remains superior to all other ferric salts.

In making a selection from the chemical processes available, each must be considered on its individual merits, with local conditions in mind. The same applies in the selection of a coagulant because economics is the basic consideration. The avoidance of complicated processes, involving a number of chemicals, or those producing heavy sludge deposits, is warranted. There appears no practical justification for the use of anything more than the most inexpensive ferric salt and pH adjustment—if required—with a minimum of acid or lime to procure the most efficient coagulation with the least sludge production. In some instances the addition of acid to cheapen or assist coagulation will be found more effective and economical than lime. In chemical precipitation, the simpler the process, the more practical and economical it becomes.

In the use of iron salts, one matter of first consequence in performance and chemical costs is that of rapid and efficient flash mixing followed by slow-motion flocculation for periods of 10 minutes and more. To preclude reduction of the iron in ferric salts and avoid indifferent coagulation, air blowing or pre-chlorination to oxidize reducing compounds in the sewage is almost essential in warm weather.

The value of pre-settling prior to coagulation has been effectively demonstrated, first, by Stevenson at Palo Alto, Cal., and on a larger scale by Hendon at Birmingham, Ala. A further and decided gain is made by withdrawing the chemical sludge from the secondary tank frequently if not continuously, and delivery into the crude sewage. Economy is attained by reduction in the amount of chemicals required, and there is also the highly practical advantage of consolidation of the dilute chemical sludge with the crude sludge in the primary tank, whence the thickened mixed sludges, carrying from 94 to 96 per cent of water, are pumped to digester or dewatering filters. Reduced disturbance in the digester, lessened heat loss, and improved quality of the materially reduced volume of supernatant digester liquor are likewise important advantages gained by the series operation of settling units and return of the chemical sludge to the crude sewage.

A real advantage secured from an hour of pre-settling is that variations in the quality of the sewage are minimized, especially for sewage likely to contain intermittent concentrations of industrial wastes. A sewage of far more uniform characteristics is thus delivered for coagulation. Furthermore, grease and other floatable matter will be confined to the primary unit, leaving the secondary precipitation tanks clean and sightly and precluding the need for frequent skimming. The return of chemical sludges, containing iron floc, to the crude sewage not only serves to adsorb non-settleables and drag them down but, if added as the sewage enters the plant, promptly combines with the volatile sulfides and serves as an odor corrective.

Problem of Increased Sludge Production and Disposal

When it comes to effectual disposal of chemical sludge, the combination of dewatering on vacuum filters and incineration bids fair to become the preferred method at the larger works. For the smaller plants, digestion will be favored provided the sludge is not too alkaline as the result of lime precipitation or not too heavily loaded with inert precipitation acids or toxic metallic compounds, such as would be produced by copper salts and the like. At several points incineration is being developed. At Dearborn, Mich., the Nichols-Herreshoff type of incinerator has been installed under a guarantee that it will successfully burn chemical sludge cake. At Winston Salem, N. C., incineration of the filter cake is being studied with the thought of recovering lime from the ash. Incineration of chemical sludge also constitutes a part of the Guggenheim process.

Digestion of Iron-Bearing Sludges Successfully Accomplished

For many years iron-bearing sludges have been successfully digested; such reasonable iron content as is found in mixed crude and chemical sludges may be expected to improve rather than hinder digestion, making for a more granular and more easily dewatered digested sludge. Furthermore, the moisture content of the sludge is lower, as is also the solids content of the supernatant liquor. The digester gas should be materially lower in sulfide content, which is so deadly to man and so destructive to gas burners, heaters, gas engines, and other appurtenances. More than likely the gas will be practically free of sulfide because of the capacity of the iron to combine with it, resulting in the production of non-volatile iron sulfide. At Birmingham and at Plainfield, N. J., no interference with sludge digestion has been noted. The sludge has been of good quality. Further, the remarkable clarity of the supernatant liquor, containing 100 ppm. of suspended solids, has been credited in large measure to the clarifying effects of the iron.

It has become evident that sewages possess varying degrees of resistance to coagulation. Some require several times the chemical dosage that others do to secure effective agglomeration of the colloidal particles. The concentrations of organic compounds and inorganic salts produce the varying degree of buffer effects which resist acid or alkali ions, productive of changes in pH value and consequent release of water from hydrophillic colloids, and induces their shrinkage and agglomeration.

Importance of Effluent Filtration

In chemical treatment filtration of the effluent deserves the same consideration that it should be given as an adjunct to the activated sludge process. Few activated sludge plants are so liberally designed as to prevent disturbance of the sludge in the final tanks during and shortly after periods of peak loadings. Also, few are free of the trouble known as sludge bulking. In both cases sludge is daily carried out with the effluent, often in appreciable volume. This condition may be corrected at considerable expense by further increasing the capacity of the final settling tank, or by raising the power input to increase aeration, or by both methods. Mechanical filtration or straining of activated sludge effluents has been successfully practiced and deserves more consideration as a means of removing suspended sludge flocs from an otherwise satisfactory effluent. Its advantages are purely economic; the painstaking and expensive attempts to maintain a sludge of high density and avoid critical velocities through tanks, to prevent sludge "leakage," may not be sound practice if the same ends can be attained more economically by straining filters.

As regards chemical precipitation, the same argument holds. At peak loading a settling period of from 60 to 90 minutes may prove inadequate to preclude the sweeping through of the lighter floc particles or those slow to form and settle in under-coagulated sewages. Strainers consisting of coarse-grained and high-rate shallow filters—preferably self-cleaning—offer a more practical measure of maintaining a uniform effluent than attempted adjustment of the chemical dosage to meet peak requirements, and one more economical than the provision of settling capacities sufficient to avoid critical floc-sweeping velocities under all loads. In water purification, engineers were not long in progressing from coagulation or softening with a long period of sedimentation to short-period sedimentation complemented by rapid filtration. Filtration of effluents probably will come to be an accepted practice at most sewage treatment plants on grounds of operating economy as well as enhanced efficiency and dependability.

Cost of Treatment

The cost of chemical treatment is a much discussed topic. Like the cost of the activated sludge process it will vary considerably with the strength of the sewage, the prices of chemicals and power, and the size of the plant. Costs have been quoted all the way from $5 to $15 per million gallons for the chemicals involved, depending on the process employed, the type of sewage treated, and the price of the chemicals. For the simplest processes, involving iron salts with or without lime in moderate dosages, the quoted figures of $5.60 to $6.50 per million gallons for chemicals seem supportable.

At the Shades Valley Plant of Birmingham, Ala., which treats 1 mgd., the simplest of the chemical processes, involving the use of chlorinated copperas and pre-chlorination, has given

an excellent record of performance. The chemical costs have averaged $5.40 per million gallons with copperas at $17.50 per ton and chlorine, in ton containers, at 3 cents per lb.—prices that are none too reasonable. On another Birmingham sewage of three times the strength—an oxygen demand of 300 and 310 ppm. of suspended solids—experimental plant operation during a period of weeks has justified the predicted chemical costs of $6.50 and total operating and fixed charges for a 12-mgd. installation, costing $212,000, of $13.84 per million gallons. The latter estimate is based on continuous use of the precipitation process, involving average chemical dosages as determined.

If the chemicals are needed only 6 months in the year, their average annual cost becomes $3.25 per million gallons, which, added to the other operating and fixed charges of $7.34, gives a yearly average total of $10.60 per million gallons. This amount slides downward toward $7.34, depending on how much below 180 days per year the chemical treatment is used. The costs at Birmingham are cited because of the comparison that can be drawn between two plants having the same type of equipment and supervision—a small plant treating a relatively weak sewage and a 12-mgd. plant receiving a relatively strong sewage from the same municipality.

Future Outlook for Chemical Treatment of Sewage

Considered as an intermediate process, effective in varying degrees according to varying conditions and adapted to intermittent or continuous application, chemical treatment demands due consideration. The increasingly difficult problem of trade-waste disposal, and the effects of such wastes on more favored biological processes, would indicate an expanding demand for chemical treatment of both municipal and industrial sewages. These may be treated in whole or in part, and the chemical process may be the only one used or it may be employed to prepare difficult sewages for further treatment biologically. In either case its application may become seasonal only.

There is definite indication that a combination of sedimentation and chemical precipitation will be productive of the greatest improvement in average stream conditions for the smallest investment in plant structures and appurtenances, and the lowest fixed charges and operating costs. In some cases, biological treatment will be required either alone or to supplement chemical treatment.

In the hands of plant operators, chemical treatment should become a valued "shock absorber" to reduce the loadings on biological plants during peak hours on certain days in the week or weeks in the year. To relieve odors and prevent the attack of sewer gas on masonry, the addition of iron salts to sewers above the point of odor nuisance or structure damage has much to commend it, as evidenced by results already attained.

Combination plants, including chemical precipitation and the old, reliable, and rugged trickling filter, should be considered for small and medium-sized installations. In such cases the filter loading will be limited possibly only by the amount of liquid it can pass without "drowning." This is because the organic content, especially the slime-producing part, which most seriously loads trickling filters and necessitates coarse media with large voids, will have been almost completely removed as will also the odor-producing compounds and fly-breeding substances that accumulate on the upper stones. At points where there is a marked seasonal variation in population, chemical precipitation prior to filtration can be suspended during seasons of low load. Thus, for resorts this combination is most promising, practical, and economical. Its advantages cannot be overlooked by the sewage economist, and deserve the careful consideration of engineers.

(*Since the above article appeared the Committee on Sewage Disposal of the American Public Health Association has rendered a voluminous and thorough report on "Chemical Treatment of Sewage," which has appeared in the November,* 1935, *issue of Sewage Works Journal. This timely report of* 111 *pages is too lengthy for reproduction here, and, therefore, the "Conclusions" only can be presented.—Editor.*)

CHEMICAL TREATMENT OF SEWAGE

(Excerpt from Report of the Committee on Sewage Disposal of the American Public Health Association.)

The above committee dealing with "Chemical Treatment of Sewage" rendered its searching and voluminous report of 111 pages before the Association on October 8, 1935, at Milwaukee, Wis. It was printed in full in the November, 1935, issue of *Sewage Works Journal.**

The following constitute the Conclusions drawn at the end of the report.

The chemical treatment of sewage includes a wide range of effort. From the data cited herein it would appear:

1. Chemical treatment usually accomplishes a degree of treatment between plain sedimentation and biological processes.

2. By the addition of a zeolite filter following precipitation with generous amounts of chemical, the Guggenheim process substantially equalled an activated sludge effluent.

3. The seasonal or occasional use of chemicals is attracting favorable notice in situations where sedimentation alone may suffice for the greater part of the year or for many years out of a cycle.

4. The use of chemicals as a preparatory treatment in addition to sedimentation ahead of biological filters is practiced in many situations, and prolongs the useful life of existing plants, otherwise overloaded.

5. Of the various processes for chemical treatment of sewage considered in the United States, the use of iron salts, particularly ferric chloride or ferric sulphate seems most favored.

6. The manufacture of iron salts from scrap iron or tin cans with chlorine has been favored in many situations for reasons of economy.

7. The use of iron salts, particularly ferric chloride, for sludge conditioning prior to vacuum filtration has been generally adopted where practicable.

8. The comparison of chemical treatment of sewage with other procedures should be studied carefully from the standpoint of adequacy, performance, and cost.

9. The use of chemical treatment in handling industrial wastes appears to have a definite place, where performance and cost justify the procedure as compared with other methods.

The Committee presents this report as a summary. If errors are found or additional data are available, the Committee would welcome the information at an early date, if sent to the chairman.

Langdon Pearse, chairman; Harrison P. Eddy, Willen Rudolfs, C. E. Keefer, P. J. A. Zeller, F. W. Mohlman, C. K. Calvert, A. M. Buswell, A. E. Berry, F. M. Veatch.

*Reprints of the report may be had from WATER WORKS AND SEWERAGE as long as the supply lasts.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM*
New York City

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

*Associate, Alexander Potter Engineers, New York, N. Y.

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour

TABLE NO. 1 — DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential; Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29, 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System; Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24, 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System; Residential, with some Industries and some Business Districts	14.19	298,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, Ga. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

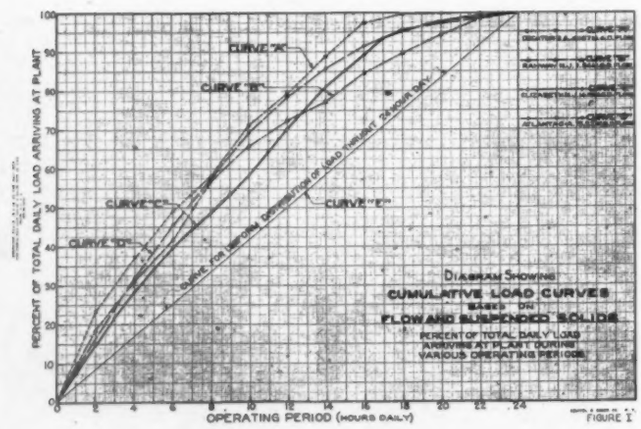


Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

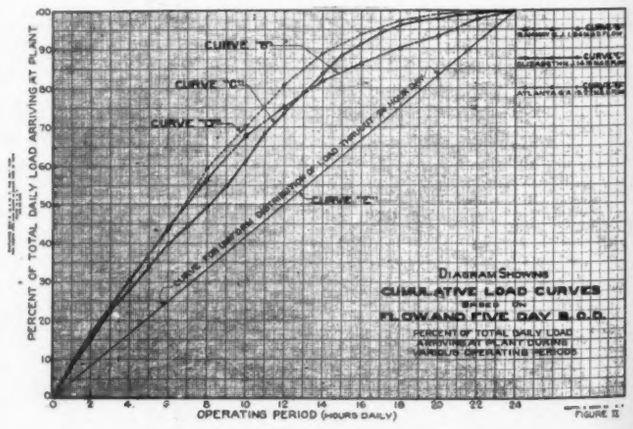


Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first, the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, way be used for the study.

Typical examples of such curves, showing data for the four systems investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the latter upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants; in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

Specimen of Sewer Choker. This "Bush" Supported by a Single Feeder

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing,* a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

NOTE: The above operating "kink" appeared in the March, 1933, issue of WATER WORKS AND SEWERAGE. In reply to an inquiry, Mr. McAmis makes the following comments in April 1936:

"Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots." (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush", causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

SERVICING OF POROUS AIR DIFFUSERS*

By FRANK C. ROE

Sanitary Engineer, The Carborundum Co. Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

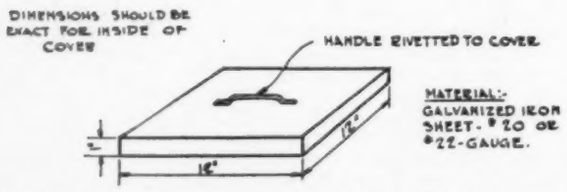

DIMENSIONS SHOULD BE EXACT FOR INSIDE OF COVER
HANDLE RIVETTED TO COVER
MATERIAL:- GALVANIZED IRON SHEET - 20 OR 22-GAUGE.
18"

Plate Cover for Protecting Diffuser Plates During Setting

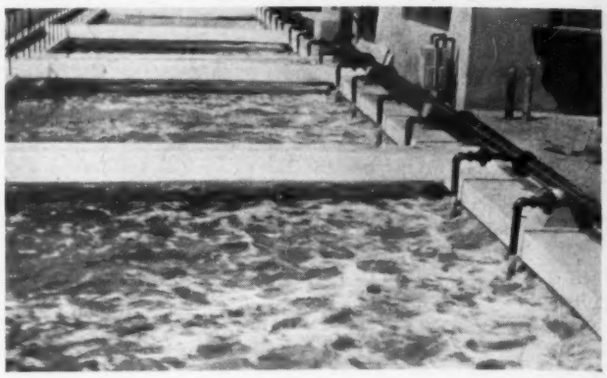


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

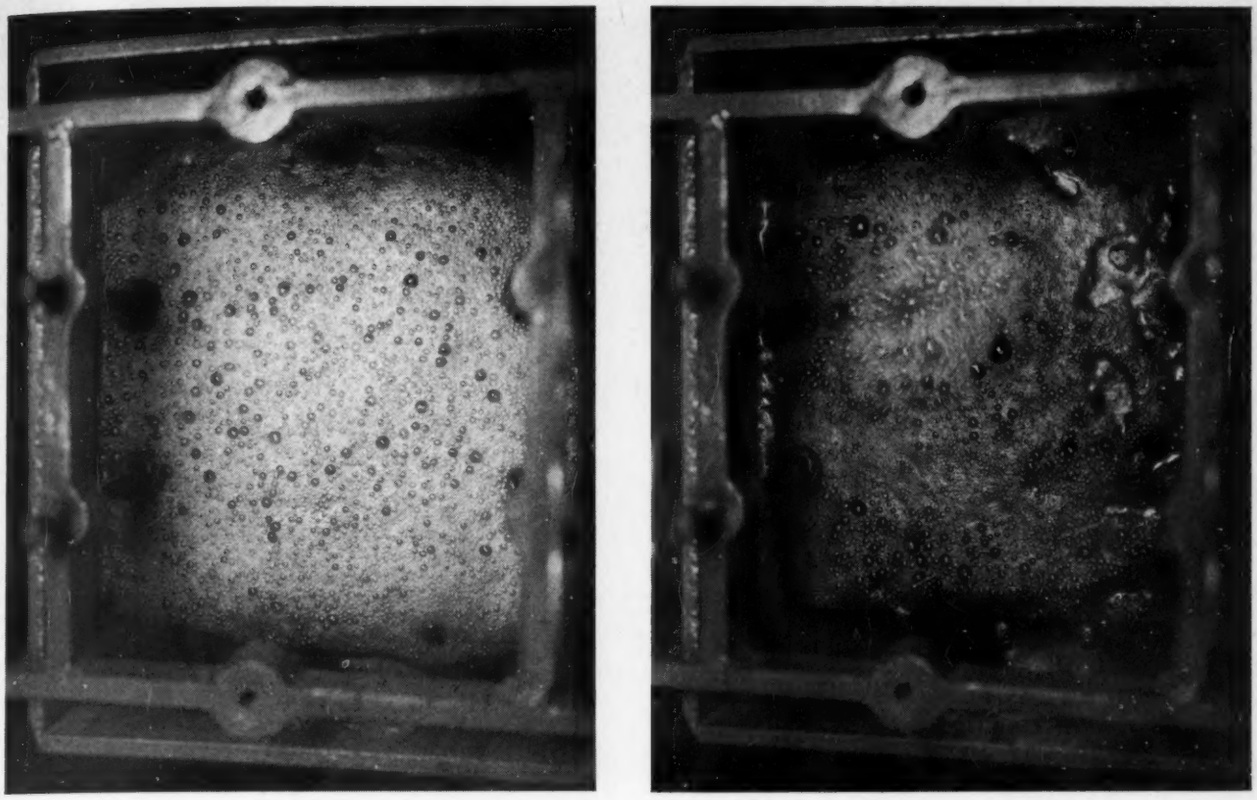


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

Plate Cover for Protecting Diffuser Plates During Setting

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

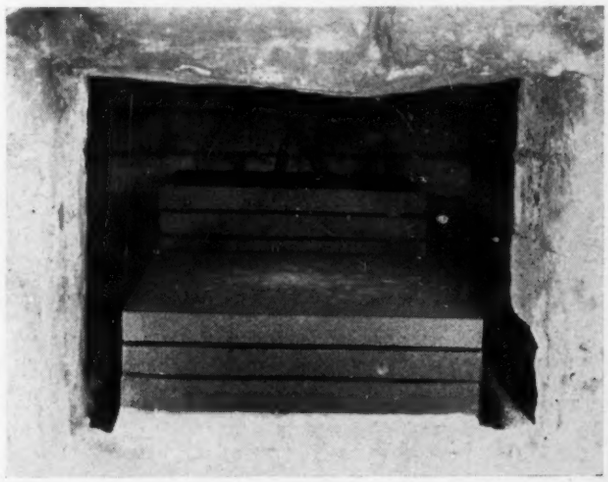


Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: This method is applicable to diffuser plates of the silica type. Dry plates by draining containers and blowing out porous structure with air at high rate. Apply blow torch flame to entire top surface of plate until it cracks into flakes. Sweep off this film or scale and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air size of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

PRACTICAL ASPECTS OF STORING AND HANDLING FERRIC CHLORIDE[1]

By J. M. POTTER*

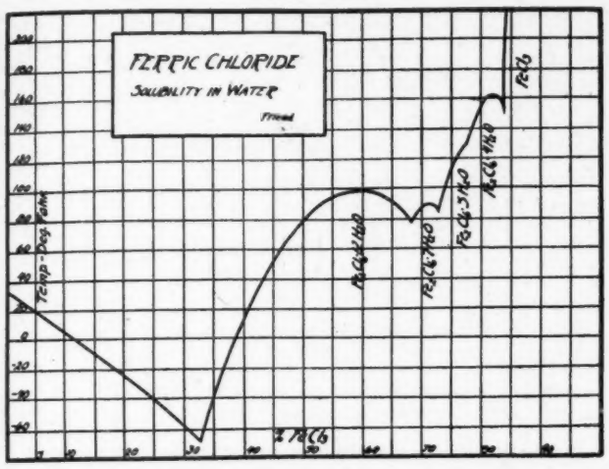
Philadelphia, Pa.

The steady advance in the utilization of chemicals in sewage treatment has created an increasing interest among engineers and municipal officials in the problems involved in their use.

The object of this article is to supply a concise outline of the more significant properties of ferric chloride and effective methods of handling and storing it.

At this time there are three commercial forms of ferric chloride available:

1. *Liquor*—An aqueous solution which is prepared to contain between 39 and 45 per cent $FeCl_3$ by weight to meet exact specifications.
2. *Crystals*—A definite crystal of the formula $FeCl_3.6H_2O$ containing 60 per cent $FeCl_3$ by weight.



Solubility of Ferric Chloride at Varying Temperatures. Note that a 45 Per Cent Solution will Crystallize at About 52 Degrees F.; a 33 Per Cent at Zero.

3. *Anhydrous*—A complete water-free form containing 98 per cent or more $FeCl_3$ by weight.

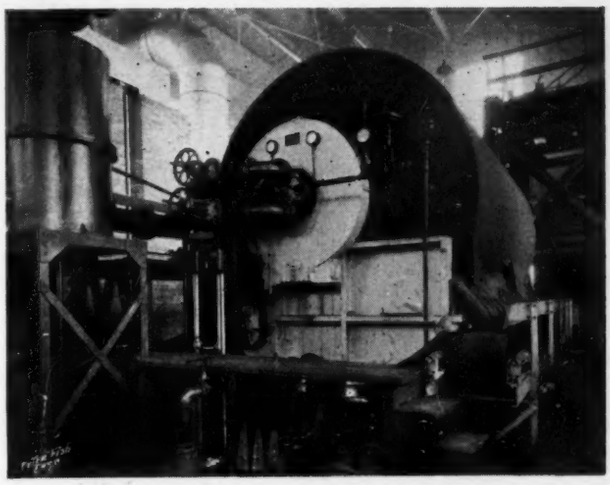
Liquid Ferric Chloride

Commercial ferric chloride liquor is a dark brown, somewhat oily appearing aqueous solution of varying concentrations. Obviously for the lowest transportation cost, the $FeCl_3$ content of these solutions should be as high as possible but concentrations are limited by crystallizing temperature conditions during transit or storage. To prevent crystallization the strength of solutions usually varies from 45 per cent in midsummer to 39 per cent $FeCl_3$ in midwinter. Average concentration of shipments over a period of several years has been 42 per cent.

Shipments are made in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 pounds of dissolved $FeCl_3$ per car. The dome of the tank car is equipped with sump and center level discharges, a filling and air pressure pipe with gauge connection and a rubber disk safety valve which relieves at gauge pressures exceeding 25 pounds. The car is unloaded by attaching a rubber hose to the discharge connection and siphoning in case of low level storage tanks or by applying air pressure up to 25 pounds where a lift is required.

The maximum lift by air ejection is limited to 40 feet. If higher lifts are necessary a suitable pump should be provided.

Ferric chloride liquor (referred to in the trade as liquid ferric chloride) is easily handled and is usually the most economical form for use by the large consumer, who is reasonably near a source of supply. However, it has the disadvantage of requiring transportation costs on its 58 per cent (average) water content, railroad siding facilities, and storage tanks for one or more cars.



Filter and Sludge Conditioning Tank—Chicago Sanitary District. Here the Operations are Under the Control of an "Electric-eye".

Storage Tanks

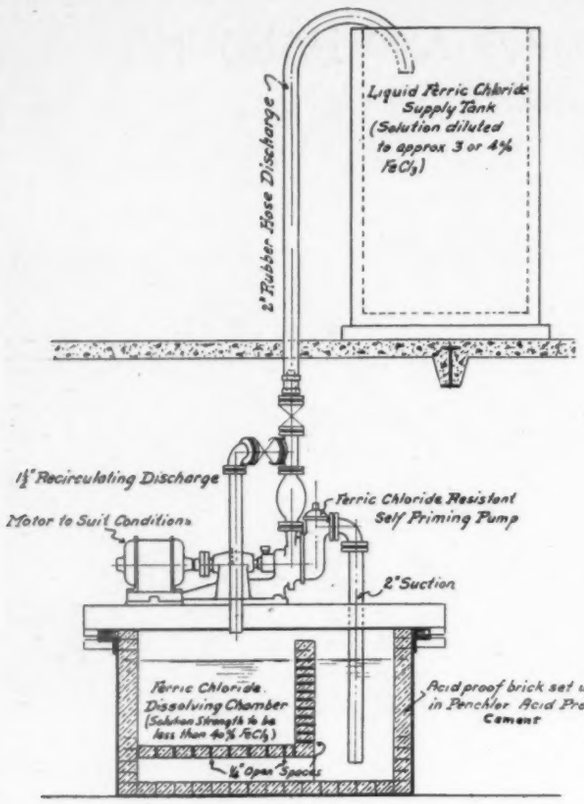
Except for its strongly corrosive nature, ferric chloride liquor offers no storage hazard, the only storage problem being provision of sufficiently large ferric chloride resistant tanks to store one or more carloads. *Ten thousand gallons should be the minimum storage capacity for plants using tank cars of ferric chloride.* Wood, reinforced concrete, or steel tanks lined with rubber with all exposed exterior surfaces painted with a ferric chloride resistant paint are the ideal containers. Covered tanks need not be sheltered but, in the case of unsheltered tanks, the strong liquor received during warm weather should be diluted in the storage tanks during the colder months to prevent crystallization. If possible, storage tanks should be elevated to permit the liquor to flow by gravity to dilution tanks or feeders, thereby confining all pumping to the simple air lift unloading operation from the car.

The concentrated ferric chloride solution taken from storage is preferably diluted to a 2 or 3 per cent solution when applied

Ferric Chloride Dissolving Tank—Hagerstown, Md. Sewage Treatment Works. Steel Tank with Rubber Lining and Faced with Acid-proof Protecting Brick Laid with Acid-proof Cement. Anhydrous Ferric Chloride in Non-returnable Steel Drums Stocked in Rear.

*Chemical Engineer, Technical Service Dept., Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.

[1]From WATER WORKS AND SEWERAGE, January, 1935.


Liquid Ferric Chloride Supply Tank (Solution diluted to approx 3 or 4% FeCl3)
2" Rubber Hose Discharge
1½" Recirculating Discharge
Ferric Chloride Resistant Self Priming Pump
Motor to Suit Conditions
2" Suction
Ferric Chloride Dissolving Chamber (Solution Strength to be less than 40% FeCl3)
Acid proof brick set up in Penchlor Acid Proof Cement
½" Open Spaces

TYPICAL ARRANGEMENT of ANHYDROUS FERRIC CHLORIDE MIXING AND PUMPING UNIT

Sketch of Trouble Free Equipment and Method of Dissolving, Diluting and Feeding Ferric Chloride.

by one of the methods noted later in this article under "Feeding Equipment." Rubber-lined wood tanks under cover serve the Sewage Treatment Works of Milwaukee.

Crystal Ferric Chloride

Crystal ferric chloride is the oldest commercial form. As indicated in the accompanying graph, four hydrated crystals of ferric chloride can be formed; but, only the dodecahydrate, $Fe_2Cl_6.12H_2O$, (commonly written $FeCl_3.6H_2O$) is now commercially available. This material contains 60 per cent $FeCl_3$ by weight, is in the form of large yellow or brown lumps, has a melting point of 98.6° F., is slowly soluble in water at average tap temperatures, and is moderately hygroscopic.

The crystals are marketed in non-returnable, hardwood, paraffine-lined barrels of 55 gallons' capacity, which contain approximately 435 pounds of material. To prevent melting, and possible leakage, it is advisable to store barrels in single tiers under dry conditions at temperatures below 98.6° F. *The storage space required is approximately 70 square feet per ton of $FeCl_3$.*

Equipment for preparation of solutions and feeding crystal ferric chloride will be discussed in connection with anhydrous ferric chloride solutions, because of the close similarity of each.

Anhydrous Ferric Chloride

Anhydrous ferric chloride occurs rarely in nature, possibly the only source being the lava of Vesuvius. It takes the form of small greenish-black crystals with a melting point of 577.4° F., and is extremely hygroscopic, being readily soluble in water to 45 per cent concentrations at room temperatures above 55 degrees.

At present, the anhydrous form is being shipped in non-returnable steel drums holding 150 pounds of material. The drums, 15½ inches in diameter by 20 in height and weighing 10 pounds, are fitted with a 9-inch air-tight gasket and lid held in place by 4 screw bolts. These drums are convenient packages which may be stacked and stored indefinitely without deterioration. *Storage space required is approximately 40 cubic feet per ton of $FeCl_3$.*

Anhydrous ferric chloride has a decided advantage over the other forms by reducing transportation costs and storage space requirements 40 per cent or more. In addition, waste by leakage or deterioration is eliminated.

Preparation of Solution, Feed Methods And Equipment

The hygroscopic character of ferric chloride prohibits the use of dry feeds. The corrosive nature of solutions prevents the use of ordinary piping and feeding equipment. A 20 per cent ferric chloride solution rapidly attacks the common metals and dehydrates wood, causing it to warp and shrink. Wood, or reinforced concrete, resists the action of weak solutions since excessive hydrolysis forms a protective hydrate coating. Equipment made of, or lined with, rubber, glass, Bakelite, or ceramic material, or the resistant metals such as Durichlor, or Hastelloy "C," will resist all concentrations of ferric chloride at normal temperatures. Rubber, glass, or ceramic materials may require additional protection against mechanical abrasion, or heat variation.

Feeding apparatus may vary from a simple solution tank with constant head orifice box to a modern "electric eye" controlled installation such as that used at the Chicago Sanitary District. The ideal and foolproof method of feeding involves 3 distinct steps: (1) Solution, (2) Dilution, (3) Application.

Dissolving Tanks

Solution tanks are necessary for dissolving either the crystal or anhydrous ferric chloride. Concentrations of less than 40 per cent are recommended to prevent crystallization and, in the case of anhydrous ferric chloride, high temperatures at the time of preparing the strong solution.

Solution strengths should be determined by adding a weighed quantity of ferric chloride to a definite volume of water as hydrometer measurements have proved to be unreliable. The tank should be at least partly filled with water before adding anhydrous ferric chloride to prevent the formation of the slowly soluble higher crystals and if the total contents of a drum are not added at one time the lid should be tightly replaced. Solution tanks of steel, reinforced concrete, or wood, lined with rubber and faced with acid-proof brick and cement, and of sufficient size to dissolve a 12 hour supply of ferric chloride, are preferable. A material rack, or compartment, and mechanical means of agitation are desirable features. Here illustrated is such a tank in connection with a pump which serves the dual purpose of agitating and lifting the concentrated liquor to the dilution tank above. A similar tank is in use at Hagerstown, Md., where the solution is raised to the dilution tank by a vacuum lift.

Ferric Chloride Service Tank—Rubber Lined. Note Hose Connections and the "Saunders" Pinch-type Diaphragm Valves for Corrosive Liquids. Dearborn, Mich., Sewage Treatment Works.

Dilution Tanks

Dilution tanks are advisable for preparing and supplying uniform solutions to feeders. Concentrated solutions are diluted to 3 or 4 per cent $FeCl_3$ by adding gauged volumes of water and liquor. Experience indicates that stronger than 5 per cent solutions exhibit intense localized reaction on application and solutions weaker than 2 per cent may be appreciably hydrolyzed, especially by diluting waters of high alkalinity. Dilution tanks may be similar in construction to solution tanks without the acid-proof brick facing. Reinforced concrete tanks painted with a ferric chloride resistant paint, or large stoneware crocks are suitable. Other desirable features would include a mechanical stirrer, a graduated gauge rod, or glass, and a capacity for at least 4 hours' supply of solution. A tank with the depth exceeding other dimensions is preferable for more accurate gauging.

Solution Feeder

A positive displacement or a variable siphon head type of solution feeder is recommended for applying ferric chloride solutions. Several such corrosion resistant feeders, which have entirely corrected the uncertain performance peculiar to the old orifice type feeder, are on the market today. These feeders may be either manually or automatically regulated. Space does not permit even a limited discussion of all such feeders but following is a list of manufacturers: Builders Iron Foundry, Providence, Rhode Island; Galigher Company, Salt Lake City, Utah; Hills-McCanna Co., New York City; Omega Machine Co., Kansas City, Mo.; Phipps & Bird, Inc., Richmond, Va.; Wallace & Tiernan, Inc., Newark, N. J.

Obviously, a gravity flow from solution tank to the final point of application is the ideal feeding arrangement. When lifting is necessary, any method which employs ferric chloride resistant materials may be used. Rubber-lined or hard rubber pumps, pipe and fittings are satisfactory for handling ferric chloride solutions at normal temperatures. Equipment made of Durichlor, or Hastelloy "C" is recommended for hot solutions.

For simple coagulation of sewages with ferric chloride, water purification practice for flocculation and sedimentation will give the best results. For sludge conditioning rapid agitation for 5 or 6 minutes followed by continuous filtration is preferable to the batch method.

SEWER CLEANING WITH RUBBER BEACH BALLS

By A. M. RAWN, C.E.*

Los Angeles, Calif.

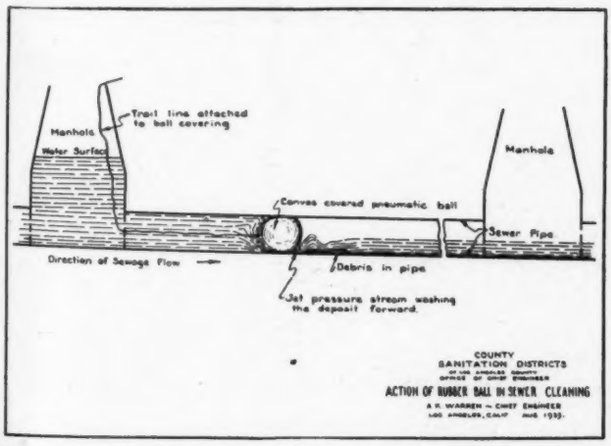
During construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.



Sketch Showing Action of Beach Ball During Sewer Cleaning

Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for complete removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate. The ball was put through again immediately and appeared at the outlets in less than an hour.

*Asst. Chief Engr., Los Angeles County Sanitation District, Los Angeles.

ACTIVATED SLUDGE THICKENING*

By D. TRAVAINI

Superintendent, Sewage Treatment Works, Phoenix, Ariz.

Phoenix, Arizona, has an activated sludge plant with Dorrco aerators, and utilizes separate digestion of mixed crude sludge solids and the wasted activated sludge. C. C. Kennedy, Consulting Engineer, who designed the plant, provided a sludge thickener for the purpose of concentrating activated sludge.

The sludge thickener, as constructed, is a circular tank 35 ft. in diameter with an effective depth of 9 ft. at the periphery of the tank with 1 ft. of free board above the water level. The thickening mechanism was supplied by the Dorr Company and consists of a picket fence made of 2-in. pipe on 6-in. centers extending 5 ft. above the bottom of the tank floor. This is attached to the bracing supporting the bottom scrapers. A skimming arm is also provided. See Fig. 1.

The tank is centrally located and arranged so that waste activated sludge, mixed liquor, plant effluent, primary sludge, or digester overflow liquor can be admitted through pipe inlets at one side of the tank, approximately 18 ins. below the water level.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

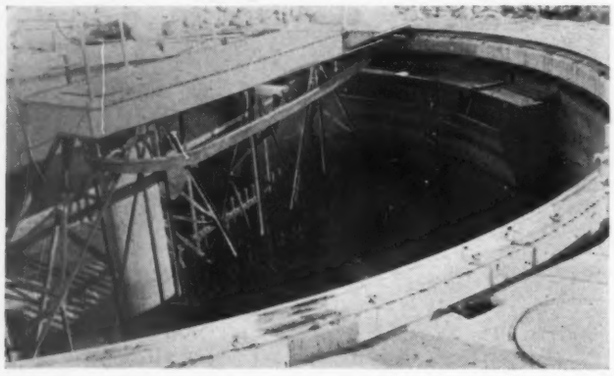


Fig. 1—Thickener Mechanism Showing Picket Fence Bottom Scrapers and the Sacramento Type Inlet Baffle

Fig. 2—Sacramento Baffle and One of the Three Chlorine Hose Inlets

A 24-in. redwood baffle 13 ft. long was provided in front of the pipe inlets.

The original baffle at the inlet was not satisfactory. Short circuiting was so pronounced that it prevented effective utilization of the tank capacity. After considerable investigation, a Sacramento baffle was installed in May, 1933, and ended the short circuiting troubles. We attribute the successful use of the thickener to this baffle and the installation of a Wallace and Tiernan chlorinator made at the same time, the value of which will be discussed later. Before these improvements were made we were prone to look upon the thickener as a liability rather than an asset.

The Sacramento type baffle was developed under the direction of Professor Charles Gilman Hyde more than ten years ago. The structure built at Phoenix consists of a redwood baffle 24 ins. from the wall at the water surface, tapering to 9 ins. at the wall 36 ins. above the intersection of the vertical wall and sloping bottom. This baffle is perforated with 4-in. square openings on 18-in. centers, both ways. Nine inches in front of these openings

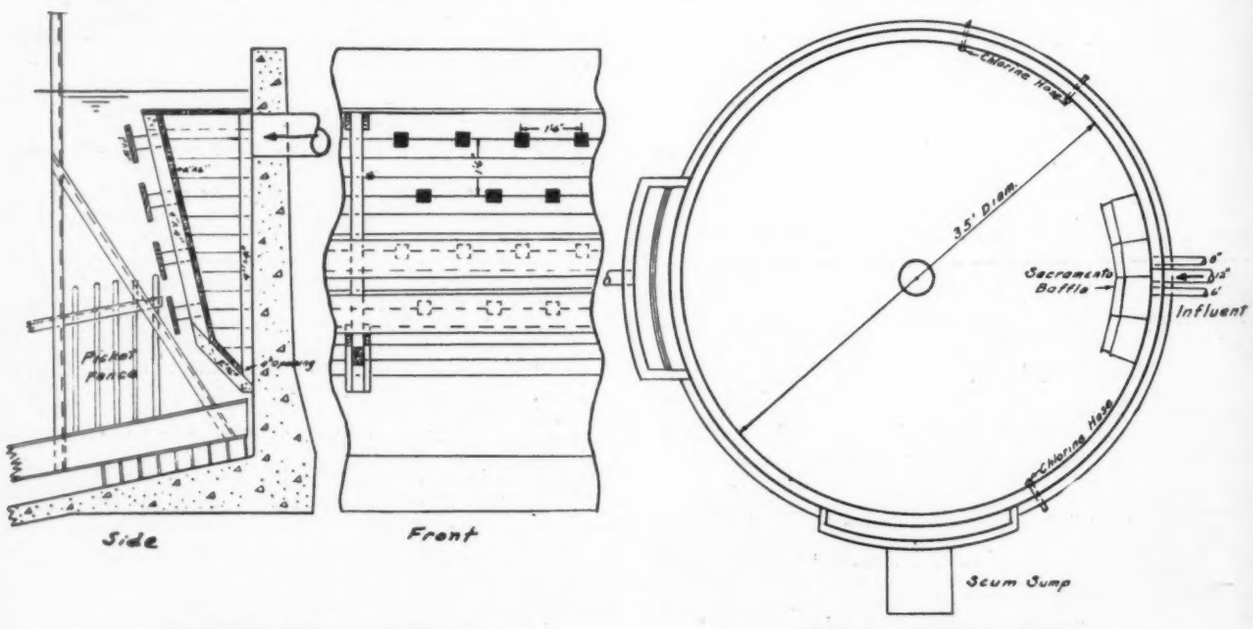


Fig. 3—Detail of Sacramento Baffle and Plan of Thickener, Showing Location of Baffle and Points of Chlorine Application

TABLE 1—RETURNED SLUDGE AND MIXED-LIQUOR (SLUDGE) THICKENING DATA. (RESULTS REPRESENT 24-HR. COMPOSITE SAMPLING.)

Date	Gals. of mixed liquor wasted	Chlorine #/24 hrs.	Influent (Mixed Liquor) pH	% by vol. 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	Thickened Sludge % Solids dry weight	pH
1/18/34	144000	35	7.6	30	1620	0.162	1075	21	20	7.6	—	—
1/19/34	144000	35	7.6	42	1725	0.172	1007	31	26	7.6	4.021	7.6
1/20/34	132000	35	7.8	50	1823	0.182	1012	31	28	7.8	4.287	7.8
1/21/34	144000	35	7.8	55	1342	0.134	1000	16	38	7.8	3.937	7.8
1/22/34	132000	30	7.6	50	1865	0.186	938	42	36	7.6	3.571	7.8
1/23/34	234000	45	7.6	47	2339	0.234	1020	26	26	7.6	4120	7.6
1/24/34	288000	53	7.6	42	1618	0.162	1074	37	46	7.6	4.090	7.6
1/25/34	207000	50	7.6	54	2232	0.223	1015	26	32	7.6	3.529	7.6
1/26/34	132000	50	7.6	40	1065	0.106	1045	13	16	7.6	3.996	7.6
1/27/34	172000	41	7.6	32	1255	0.125	909	38	30	7.6	3.827	7.6
1/28/34	158400	40	7.6	30	1863	0.186	1010	27	22	7.6	4.090	7.6
1/29/34	158400	36	7.8	28	1652	0.165	995	13	16	7.8	3.684	7.8

Date	Gals. of returned act. sludge wasted	Chlorine #/24 hrs.	Influent (Returned Activated Sldg.) pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	Thickened Sludge % Solids dry weight	pH
2/9/34	70500	60	7.6	98	5243	0.524	1210	36	106	7.6	—	—
2/10/34	60300	65	7.8	88	5651	0.565	1163	43	126	7.8	3.618	7.8
2/11/34	45200	65	7.8	99	6920	0.692	1090	28	95	7.8	3.684	7.8
2/12/34	38500	55	7.8	99	7848	0.785	1215	45	152	7.8	3.262	7.8
2/13/34	54100	65	7.8	98	8132	0.813	1230	52	166	7.8	4.127	7.8
2/14/34	19200	50	8.0	98	7337	0.734	1140	38	120	8.0	4.006	8.0
2/15/34	30300	55	7.8	98	8243	0.824	1125	45	138	7.8	3.529	7.8
2/16/34	11040	40	7.8	98	9130	0.9130	1110	32	95	7.8	3.280	7.8

Note:- Results from 24 hr. composites.

are suspended wooden baffle boards 10 ins. wide. See Figs. 2 and 3.

Operation of Thickener

Since the plant was first placed in service on March 15, 1932, the thickener operation has been diversified. We have used this structure to concentrate primary sludge, wasted activated sludge, combined primary sludge and wasted activated sludge, waste mixed liquor, combined primary sludge and waste mixed liquor, and digester overflow. The results obtained varied considerably and with some of the operations odor nuisance became a serious problem. The use of the thickener was, for the time being, abandoned.

On June 2, 1932, activated sludge had built to a point where wasting could proceed, and the thickener was again placed in service. We were unable, however, to hold the sludge in the thickener sufficiently long to obtain the degree of concentration anticipated when the tank was designed. When we attempted to hold it to increase the solid content to the point anticipated, the sludge would rise and odors became pronounced.

Attempts to Control Septicity and Short Circuiting

In the early part of October, 1932, we arranged to return plant effluent to the thickener, hoping that the dissolved oxygen in the effluent would retard septic action and thus eliminate odors and allow a longer sludge holding period. This procedure aggravated the short circuiting in the tank and caused the solids in the effluent to increase materially.

The short circuiting in the thickener made it apparent that the original baffle was not efficient and resulted in the installation of the Sacramento baffle. We also installed a Wallace and Tiernan solution feed chlorinator in order to use liquid chlorine to retard septic action. With the chlorinator we anticipated accurate control of chlorine applied to the thickener, which was not

TABLE 2—SLUDGE CONCENTRATION DATA

	Depth from liquid level in ft.	Nov. 3 1933	Dec. 11 1933	Jan. 20 1934	Feb. 11 1934
% Solids in sludge at depth shown	3	—	0.25	0.27	0.810
	4	0.50	0.50	0.70	1.02
	5	1.20	1.05	1.15	1.35
	6	1.04	1.25	1.37	1.72
	7	1.20	1.40	1.55	2.38
	8	1.40	1.70	2.10	2.87
	9	3.50	3.25	3.75	3.05
	Cone.	4.08	4.21	4.28	3.68
% Solids in sludge—Influent		0.105	0.195	0.182	0.692
pH - Influent		7.8	7.8	7.8	7.8
pH - Thickened Sludge.		7.6	7.8	7.8	7.8
Suspended Solids p.p.m. - Effluent		20	25	31	28
B.O.D. - p.p.m. Effluent		—	30	28	95

Note:- Results from 24 hr. composites.

possible under the crude conditions in which we had been using lime and chloride of lime earlier.

We devoted our spare time to experiment, to determine the efficiency of the baffle and to find at which points to chlorinate the sludge input in order to obtain the best distribution of chlorine. The results obtained from the baffle were very gratifying. By the trial and error method we selected three points of application of chlorine that gave the best distribution. The chlorine hoses are submerged 3 ft. below the liquid level in the tank. One point of application is 13 ft. along the periphery of the tank from the west end of the baffle. The other two points are 9 ft. and 18 ft., respectively, along the periphery of the tank from the east end of the baffle.—See Figs. 2 and 3.

By varying the quantity of chlorine solution applied at the points mentioned even distribution of chlorine was maintained in the surface liquor, where desired, rather than in the sludge proper.

With this preliminary work completed, during the early summer we tried concentrating primary sludge in combination with mixed liquor taken from the aeration tanks; then primary sludge with returned activated sludge, and then returned activated sludge alone. Very good results were obtained in each instance, but the trials with mixed-liquor seemed the best.

The Scheme That Gave the Best Overall Results

In August, 1933, we decided to try concentrating mixed liquor only, a method suggested by R. F. Goudey.[1]

Our object was, that in summer the primary clarifier influent is stale and we felt that by adding to the crude sewage a sizeable flow of effluent from the thickener, containing dissolved oxygen and some residual chlorine, it would improve plant operating conditions. The amount of thickener effluent would naturally be much greater when concentrating sludge from mixed liquor than when concentrating returned activated sludge and therefore the greater benefit to the crude sewage.

The results obtained by thickening mixed liquor taken from the aeration tanks were so satisfactory that we soon adopted it as routine operation. The primary sludge is concentrated to approximately 5 per cent in the primary clarifier and is mixed with the thickener sludge by pumping sludges from both tanks simultaneously to the digesters.

In Table No. 1 analytical data of thickener operations are given for mixed liquor and also when "returned" activated sludge from the clarifier was treated. Table 2 shows the solids content of the sludge at various depths. As a result the installation of the Sacramento baffle and chlorination, we can maintain a clear overflow with the sludge blanket within 3 ft. of the liquid level, when wasting 200 gpm. or less of mixed liquor or returned sludge through the thickener. The costly chlorination is considered very nominal considering its advantages.

Conclusions

Since we installed the Sacramento baffle and eliminated short circuiting, and since we started to chlorinate the top liquor to retard bacterial action and thereby control septicity, the thickener has operated satisfactorily and accomplishes the purpose for which it was designed, viz.: reducing the volume of sludge and hence the volume of supernatant liquor which is so disastrous to the activated sludge process. Likewise the need for greater digester capacity.

[1] "A New Method of Concentrating Activated Sludge," R. F. Goudey and S. M. Bennett. WATERWORKS AND SEWERAGE, May, 1933.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

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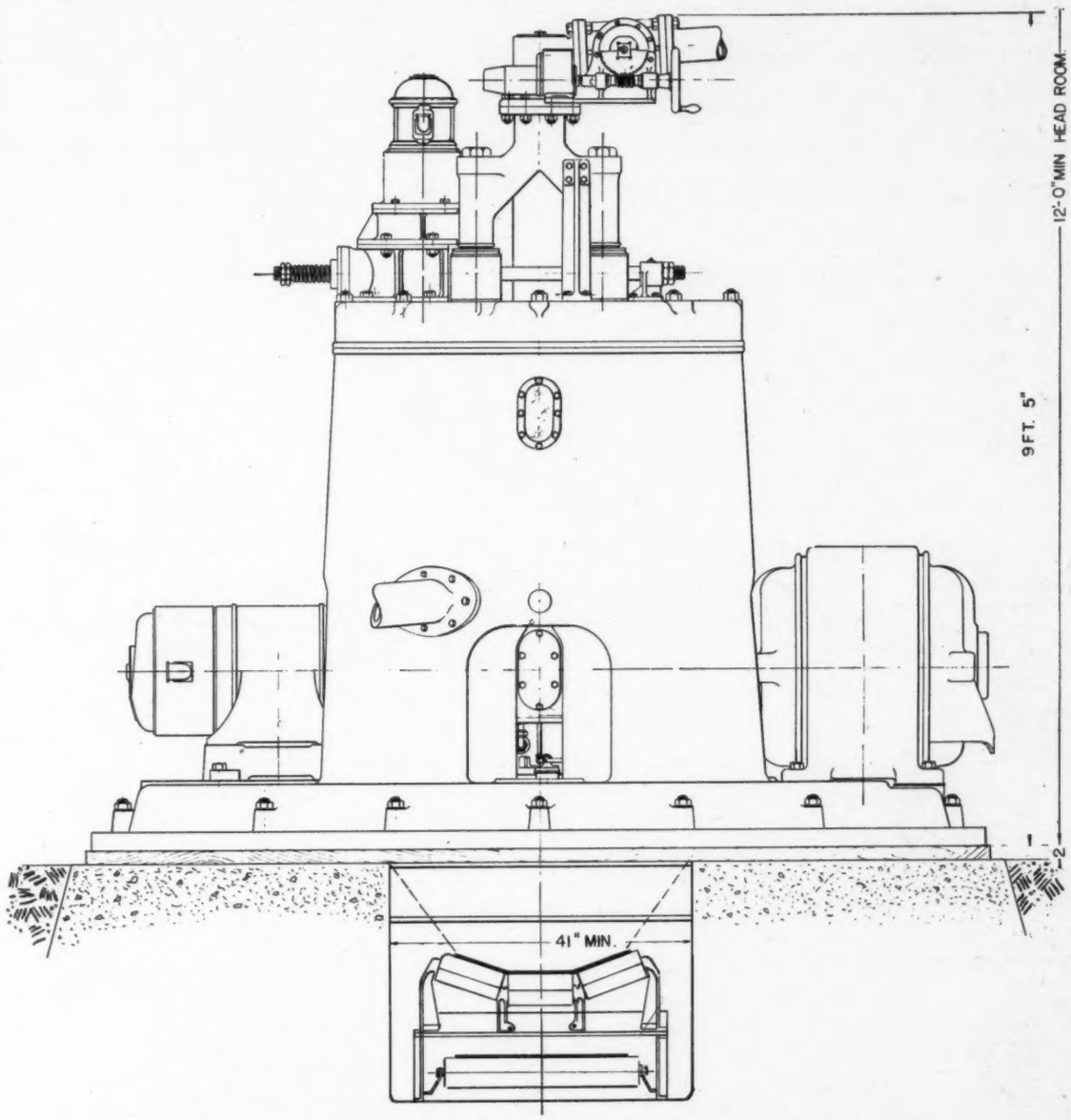

This machine was specifically developed for t he sanitary field. It offers these possibilities:

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Ideal Gas Boilers come in 41 sizes, from the smallest to the world's largest.

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Type 1-GA

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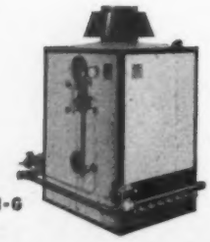


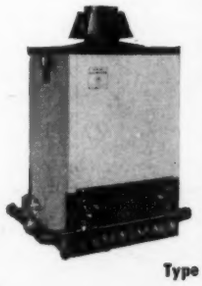
Type 1-G

IDEAL GAS BOILER CAPACITY WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HR.		BOILER SPACE		
								Floor Space	
Steam	Water	B.T.U per Hour	Sq. Ft. Steam A. G. A. Rating	Sq. Ft. Water A. G. A. Rating	B.T.U. per Hour	Cu. Ft. 700 B.T.U. Sludge Gas	Over-all Hght.	Width Front	Depth
.....	1-GA-4	31,500	.....	210	39,350	56	36¼"	14½"	22½"
.....	1-GA-5	42,000	.....	280	52,500	75	36¼	14½	25½
.....	1-GA-6	52,500	.....	350	65,600	94	36¼	14½	28½
.....	1-GA-7	63,000	.....	420	78,750	113	38	14½	31½
.....	2-GA-4	63,000	.....	420	78,750	113	41¼	19½	22½
.....	2-GA-5	84,000	.....	560	105,000	150	41¼	19½	25½
.....	2-GA-6	105,000	.....	700	131,200	188	41¼	19½	28½
.....	2-GA-7	126,000	.....	840	157,500	225	41¼	19½	31½
.....	4-GA-9	168,000	.....	1120	210,000	300	41½	28	38
.....	4-GA-11	210,000	.....	1400	262,500	375	41½	28	44
.....	4-GA-13	252,000	.....	1680	315,000	450	41½	28	50
0-GS-4	.....	64,800	270	.....	81,200	116	52	23½	28
0-GS-5	.....	86,400	360	.....	108,000	154	53	23½	31
0-GS-6	.....	108,000	450	.....	135,000	193	53	23½	34
0-GS-7	.....	129,600	540	.....	162,000	232	53	23½	37
1-GS-4	1-GW-4	146,000	610	980	182,500	261	50	35*	33¼
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	52½	39*	33¼
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	53½	43*	33¼
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	53¾	47*	33¼
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	54¾	51*	33¼
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	57½	55*	33¼
1-GS-10	1-GW-10	384,000	1600	2560	480,000	686	58¼	59*	33¼
1-GS-11	1-GW-11	424,000	1765	2820	530,030	757	58¾	63*	33¼
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	69	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	69¾	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	71½	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	72½	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	75	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	75¾	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	69¾	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	71¾	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	72½	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	75	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	75¾	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	71¾	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	72½	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	75	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	75¾	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	72½	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	75	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	75¾	218	64

*1-GS shown. The 1-GW is 4" shorter.

Type 0-G



Type 4-G

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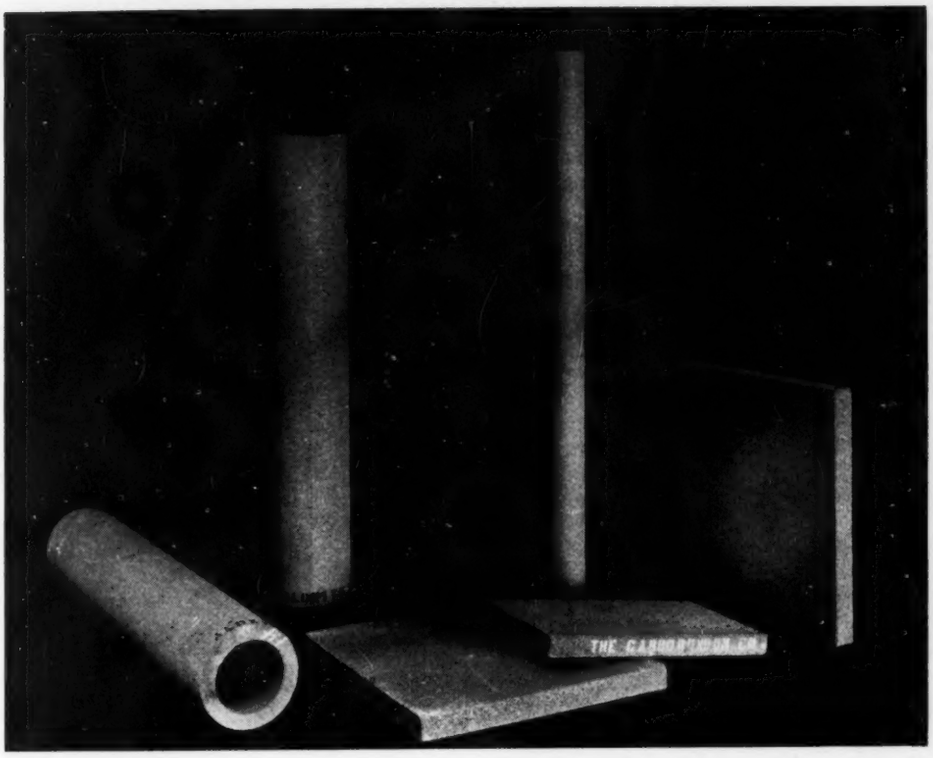

Applications

FOR SEWAGE TREATMENT

Activated Sludge Aeration.
Sedimentation Pre-Aeration.
Grit Washing and Grease Removal.
Mixing of Chemicals with sewage or sludge.
Flocculation of Chemicals.
Sedimentation Post-Aeration.
Trickling Filter Pre-Aeration.
Sludge Elutriation.

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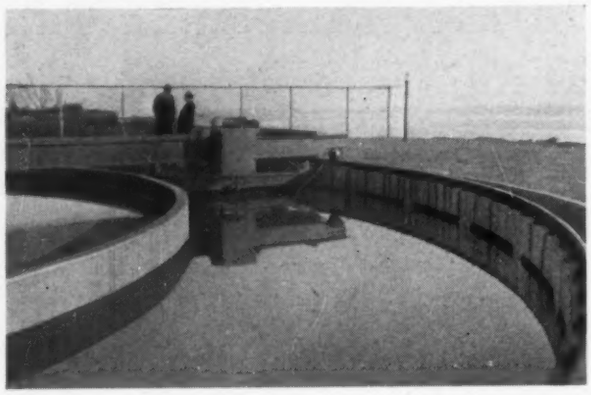
The magnetite filter accomplishes this effectively and at reasonable cost, by straining out light solids and minute impurities which cannot be removed or settled out by sedimentation.



Magnetite filter in operation.

The filter usually placed on top of a sedimentation tank (Fig. 1) consists of a bed of magnetite iron ore, screened to the size of fairly coarse sand. The ore bed is about three inches thick and is supported on a fine mesh of bronze wire.

The sewage, after the heavier solids have been allowed to settle out, passes through the screen and the ore in an upward or downward direction. The fine solids in the sewage are caught between the particles of ore, thus to a degree cleaning up the sewage.

Eventually the ore bed becomes partly choked and it is necessary to rinse or wash the ore. This is accomplished by a cleaner which passes slowly over the ore, the cleaner consisting of a bottomless box or caisson which holds a small centrifugal pump and a solenoid or electro-magnet.

As the cleaner passes slowly over the filter bed, the solenoid is alternately magnetized and demagnetized, so that a narrow strip of ore layer is alternately jerked off the wire screen and allowed to fall back.

At the same time the small centrifugal pump causes the sewage from beneath the wire screen to rush through the moving ore. This effectively cleans the portion of ore covered by the box, and when the cleaner has completed a circuit, the whole bed is cleaned. The wash water containing the impurities from the ore is caught up by the pump and passed back for retreatment or other disposal.

As the result of three years of operation of the municipal sewage treatment plant in Dearborn and one year's operation at Perth Amboy, the Automatic Magnetite Filter has brought to the art of sewage treatment the following improvements.

1. **In Plain Sedimentation** the filter reduces the usual retention period by about a quarter and the effluent is improved by 35-40%. This brings the total removal of suspended solids up to 70-75% as compared with usual removal of 50-55% attained by 2 hours of plain sedimentation. The use of the Magnetite Filter results in a saving of 35-40% of Chlorine.

2. **Chemical Process:** In the case of chemical precipitation the use of Automatic Magnetite Filters saves about 50% of the chemicals.

3. **In Activated Sludge Plants** the magnetite filter polishes or improves the effluent by removing the fine floc when plant is running perfectly. It also acts as a positive, automatic safeguard to strain the effluent in case of bulking floc or other temporary disturbance of the activated sludge process. It reduces the aeration period and the area required in final settling tanks, thus increasing the capacity of existing activated sludge plants—at the relatively small cost of adding filters to existing structures.

4. **In Trickling Filter Plants** it increases the capacity of the filters by removing fine solids cheaply, with or without chemicals, before the sprinkling filter operation. Installed after the trickling filters it protects the effluent and acts as a safeguard when the filters slough off.

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For dewatering of raw settled, chemically coagulated and activated sludges.

Built for acid or alkaline conditions.

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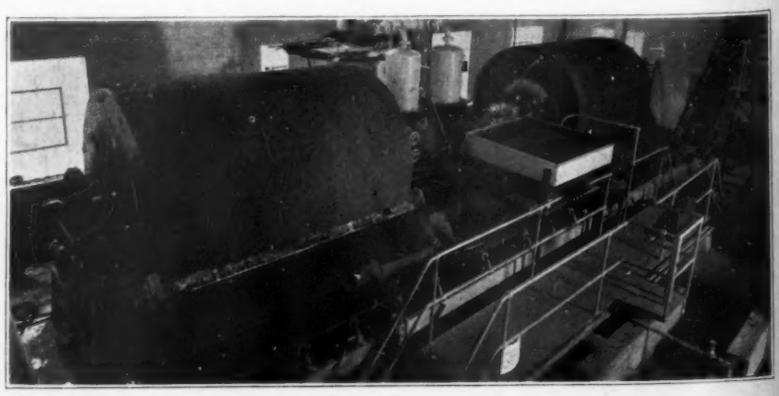
9 additional magnetite filters and 18 additional Conkey filters now under construction.

The services of this company in preparing designs and estimates of our equipment are fully available to those engaged in designing sewage treatment plants.



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Many problems peculiar to localities have been solved by Jeffrey Engineers specializing in water purification and sewage treatment. The list of Jeffrey equipped plants is growing . . . proving conclusively that modern mechanical handling of sewage is rapidly finding its place. Whatever your problems . . . our department devoted to water purification and sewage disposal is ready to work with you.

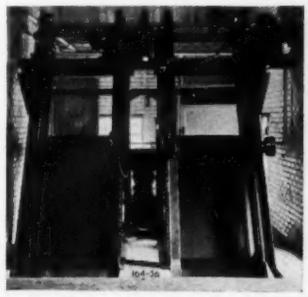
JEFFREY CONVEYOR TYPE SLUDGE COLLECTORS

For primary or secondary settling, either in sewage disposal plants or water works. Simple design guarantees efficient and trouble-free sedimentation. Wood scrapers attached at intervals to two strands of high tensile, abrasive resisting chain. High carrying capacity allows intermittent operation . . . once or twice a day is sufficient. Thicker sludge, and clearer effluent results. Operation also serves to skim floating substances to effluent end of primary sewage settling tanks. In water works may be used in free sedimentation basin, or in basin for subsequent treatment of chemically coagulated water.

Sludge Collectors installed for the City of Lancaster, Pa.

JEFFREY SELF-CLEANING BAR SCREEN

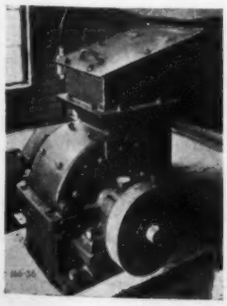
A mechanical unit of simple construction, with protective features against jamming, etc. Has no submerged sprockets or shafts. Special hinged rake design, with teeth that penetrate all the way through spaces of screen, assures thorough cleaning. Teeth of rake engage the bars at point in advance of debris accumulation. Rake is wiped clean after discharging its load.



JEFFREY COMBINED SCREEN and GRINDER

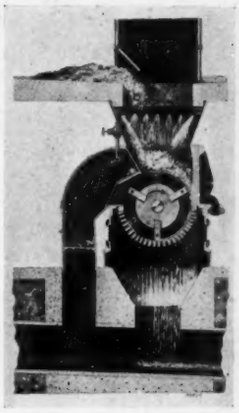
Collects, reduces to pulp and returns screenings to sewage in one direct operation. After this treatment pulp will readily pass through pumps and settle out in primary settling tanks. Units can be installed for continuous or intermittent operation. For intermittent operation an automatic electrical time device controls cycles and coordination of screening, water-spray flushing and grinding.

A Jeffrey Screen and Grinder combination recently installed is illustrated in the two accompanying pictures.



JEFFREY (Patented) GREEN GARBAGE GRINDER

Grinds garbage to pulp for introduction to existing sewage system. Inexpensive to install, this system is much more economical and satisfactory than other methods. Application of flushing water makes process odorless. Large cities may install number of units at strategic points to eliminate long hauls. Requires no skilled labor. By breaking down solids in preliminary treatment, grinder will increase over-all efficiency and lower operating cost of incineration plant.



JEFFREY-TRAYLOR CONSTANT WEIGH FEEDER

Ideal for continuous weighed feeding of hydrated lime, alum, and soda ash. Consists of an electric vibrating feeder instantly and accurately controlled electrically through counterpoised weighing belt to any desired rate of discharge. Has no regulating gates. Unit of 3,000 lbs. per hour maximum capacity can be adjusted down to feed 2 lbs. per hour . . . within 1% or less of absolute accuracy.

JEFFREY COMBINED GRIT WASHER and COLLECTOR

One conveyor in one channel both washes and collects grit, eliminating one operation. Uniform flow assured by continuous grit removal during periods of deposition. Available in two types, scraper type for ordinary purposes and V-bucket type where elevation to considerable height is desired.

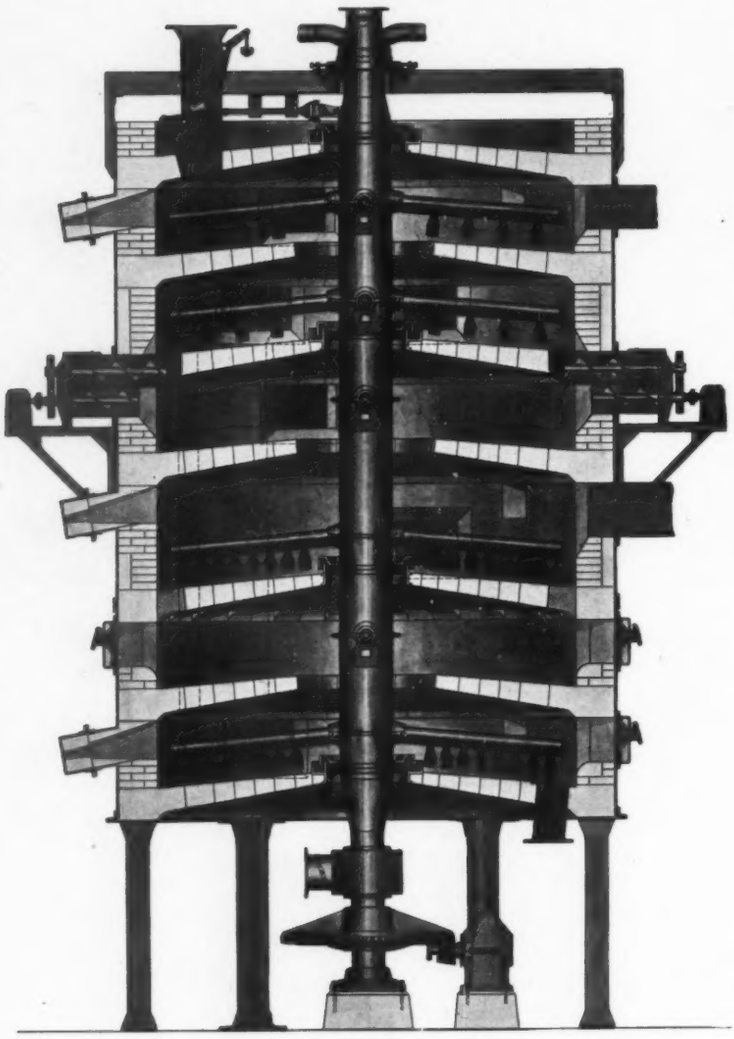
The Jeffrey Grit Washer consists of two strands of heavy heat treated malleable chain to which are attached at intervals of approximately 4 feet, plow shaped flights. Spaced alternately between a pair of plow flights is a straight scraper, or in the case of V-bucket type, a V-shaped bucket.

Water Purification and Sewage Treatment Plant Equipment by Jeffrey is completely covered in Catalog No. 615-E. Send for your copy.

MUNICIPAL SANITARY SERVICE CORP.

155 East 44th Street, New York City

ENGINEERS AND CONSTRUCTORS OF "MUNICIPAL" EQUIPMENT FOR SEWAGE TREATMENT PLANTS



DECARIE PETRO-MET MULTI-THERMO-ZONE FURNACE

Positive and Economical drying, or complete and odorless Destruction of Sewage Sludge and Screenings, effected by means of Decarie Petro-Met Incinerator—adapting greatly improved principles of Multiple Hearth Type Furnace operation. Flexible in control of air, gases and heat, thereby permitting of positive results. Its performance results in an absolute minimum in operating costs. Construction simplified. Furnace divided into separate drying and burning zones with all gases passing through a high temperature zone. We will be glad to furnish further data, and discuss your particular requirements.

RIENSCH-WURL DISC SCREENS
AUTOMATIC BAR SCREENS
COMBINATION BAR AND FINE SCREENS
AEROFLOCCULATORS
MECHANICAL AERATORS
VACUUM SEWAGE FILTERS
VACUUM SLUDGE FILTERS
MECHANICALLY CLEANED SAND FILTERS
PNEUMATIC SCREENINGS EJECTORS
SLUDGE AUTOCINERATORS
SCREENINGS INCINERATORS
DECANTERS

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, Etc.

NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

Boston	Chicago	Detroit	Lexington	Omaha	Seattle
Bridgeport	Cleveland	Indianapolis	Los Angeles	Philadelphia	St. Louis
Buffalo	Columbus	Jacksonville	Madison	Pittsburgh	Syracuse
Charlotte	Dallas	Kansas City	Minneapolis	Roanoke	Washington, D. C.
Chattanooga	Denver	Knoxville	Oklahoma City	San Francisco	

WALLACE & TIERNAN, Ltd., Toronto, Canada **WALLACE & TIERNAN, Ltd., Montreal, Canada**
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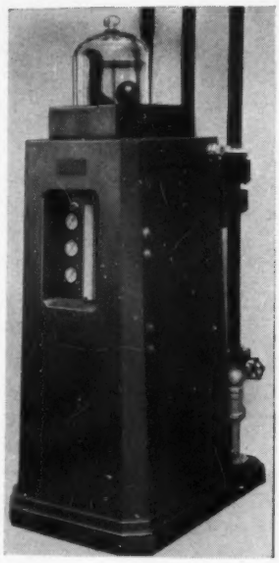
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and removal of settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and as a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary processes of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 2000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purifiication processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.

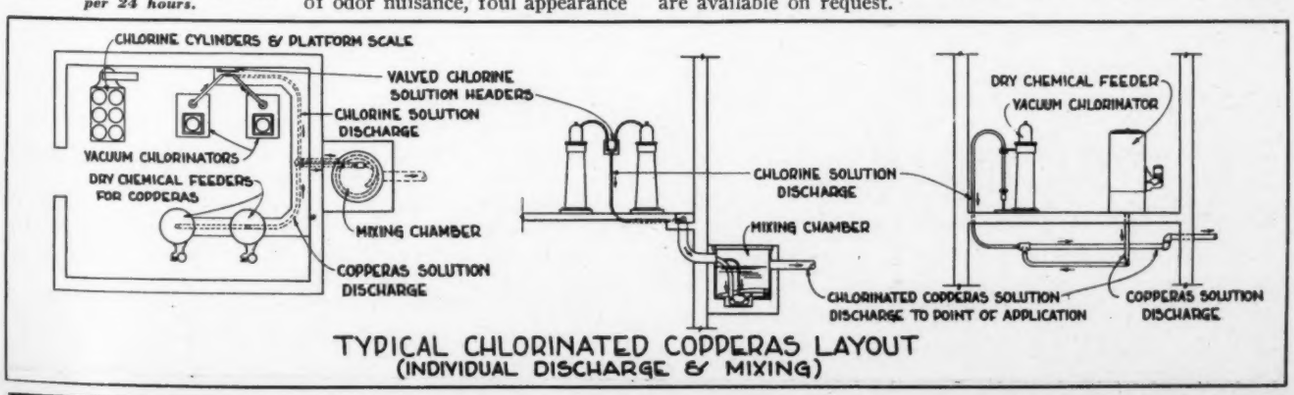
Installation of four Visible Vacuum Chlorinators at the New Haven, Conn., Sewage Disposal Plant.

IRON SALTS IN SEWAGE TREATMENT

Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnish the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.



TYPICAL CHLORINATED COPPERAS LAYOUT
(INDIVIDUAL DISCHARGE & MIXING)

SERVICISED PRODUCTS CORPORATION

Telephone Grove Hill 0423

MANUFACTURERS AND ENGINEERS

6051 West 65th Street (Clearing Station), Chicago, Ill.

Factories: **Chicago, Ill., Syracuse, N. Y., Wilmington, Del.**

Distributors and Dealers in Principal Trading Centers

PRODUCTS—

Premoulded Sewer Pipe Belt
Quick Drying (Q.D.) Asphalt Primer
Asphalt Compounds (for Hot Poured Joints)
Bitupak Calking Material
Tufflex Plastic Cement
Sewer Liners. Asphalt Planking

PRODUCTS—

Tunnel Liners. Bridge Paving
Water Proofing Protection Course
Highway Crossing Rail Filler
Expansion Joints
Rubber Tile Flooring. Copper Coated Roofing

SERVICISED PREMOULDED SEWER PIPE JOINT

An Improved Material for Making Better, Tighter, More Flexible and More Economical Sewer Joint

Fig. 1. A Section of Servicised Sewer Pipe Belt.

What It Is:

Servicised Premoulded Sewer Pipe Belt is composed of a uniform mixture of selected fibrous matter with refined bitumens of special character, and formed into wedge shaped strips for easy handling and to facilitate calking.

These wedge shaped strips are made in various dimensions of cross-section and in various lengths to take care of the usual sizes of sewer pipe, and in each case to properly fill the annular space between the bell and spigot at the joints. The wedge shaped cross section not only conforms to the shape of the bell, but gives a wedging action as the belt is driven into place.

This wedging action, together with the flexible quality of the material insures tightness of the joint, as the belt accommodates itself to small irregularities or variations in the pipe, and yet are *within the limits of allowance* in standard sewer pipe specifications.

Servicised Premoulded Sewer Belt is manufactured to fit sewer pipe from 4″ to 36″ in diameter, and made according to dimensional standards set up by the American Society for Testing Materials and the American Society of Municipal Improvement.

Why Fibrated Asphalt for Sewer Joints?

For many years in different forms and under different methods of application, asphalt has been recognized as the *best* material for making sewer joints.

Servicised bituminous joints, when they are made to fill the annular space, and put in with any degree of skill, are waterproof, rootproof, acid-proof and flexible. These are highly desirable qualities and are not possessed completely by any other material.

Fig. 2. A Sewer Pipe Belt in Place.

On account of the brittle nature of sewer pipes, flexibility is an especially desirable quality in a sewer jointing and asphalt compounds possess this feature. Each year thousands of dollars are spent by municipalities for making repairs to sewers, and the cause in most cases leads back to imperfect joints.

Chief among the reasons why sewers cease to function and require repair are, (1) broken places in the line through trench settlement or ground movement; (2) stoppage of the sewer by foreign matter such as soil or root growths. The first of these conditions is aggravated by unyielding, stiff joints; the second by breaks in the pipe and by imperfect or incomplete joints which occur frequently when attempts are made to use cement mortar or hot asphalt in wet trenches.

The use of fibrated bituminous jointing material remedies this condition very largely. Therefore, the invention of a moulded bituminous belt which could be handled by the usual labor, and which would make tight and complete joints under any and all weather conditions.

Any modern sewer system which includes a sewage disposal plant or where sewage has to be pumped or handled through processes, requires tight sewer joints to make the operations efficient. Open joints or breaks in the sewer lines will permit the entrance of ground water, increasing the work to be done, and its cost and reducing the efficiency of the disposal station.

Servicised Fibrated Bituminous Joints are always flexible and light.

SERVICISED PREMOULDED SEWER PIPE BELT

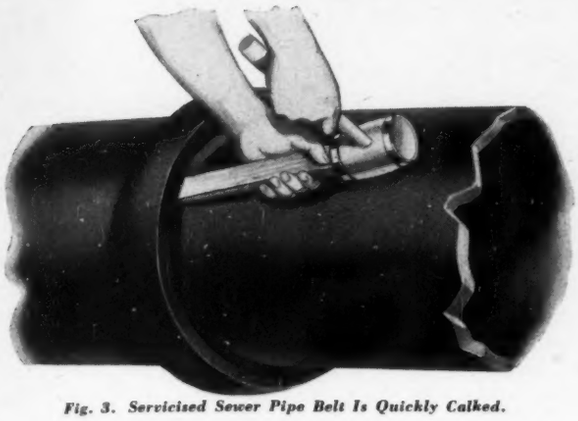


Fig. 3. Servicised Sewer Pipe Belt Is Quickly Calked.

The Advantages of Servicised Premoulded Sewer Belt:

1. **Tight Joints:** The space between spigot and bell is completely filled with water-tight material cohering closely to the sewer pipe and always remaining flexible.

2. **Flexible Joints:** Joints which accommodate themselves to ordinary trench settlement or ground movements, the joint remaining tight and preventing any strain on the pipe at the bell.

3. **Root-Proof:** The moulded, fibrated asphalt belt entirely filling the joint, prevents roots from entering and stopping the pipe.

4. **Resistent to Acids:** The jointing is not affected by ordinary acids or by sewer liquors.

5. **Easily Installed** and usable even under the worst weather or trench conditions. Material cannot wash away as it is impervious to water.

6. **Economical:** There is no waste of material as the belt is moulded to size and cut the right length for the pipe.

7. **Ease of Inspection:** An inspector can see from the top of the trench that the joint is properly made.

8. **Labor Saving:** Premoulded Sewer Belt is foolproof. The design is such that it can only be set in its proper position. No excavation need be made under the bell of the pipe as the jointing material is placed prior to entering the spigot. The use of this jointing material centers the pipe automatically.

These advantages operate to increase the *speed* of making joints and therefore *materially reduce* the *cost* of *labor.*

With a little experience the contractor will find that this saving in labor will at least offset the difference in cost between this and the cheapest other material, but with the result that a much better and more creditable job is produced.

Installation of Premoulded Sewer Belt:

For convenience in handling, belts for sewer pipe more than 8 inches in diameter are made in sections as shown in table.

Fig. 4. Inserting Belt Prior to Calking

In the illustration, Fig. 2, the lower arrow points to a section of premoulded belt packing placed in the bottom of the bell. The spigot of the next section of pipe is next inserted in the bell and allowed to rest on this lower section of belt. It is then worked to proper line and grade in the trench, and then the upper section or sections of belt are inserted in the spaces indicated by the upper arrow, and calked tight. As this operation compresses the lower section of belt packing, there is no necessity for calking at the bottom or for excavating under the bell.

Servicised Belts for the smaller sizes of sewer pipe are made in one piece and are installed in essentially the same manner, the center of the belt being placed in the bottom of the bell with the ends protruding at the top. After the spigot of the next pipe section has been inserted and the pipe worked to line and grade, the ends are folded over, driven into place and calked.

It should be noted that pipe sections are placed at line and grade before joints are calked, and that there can be no disturbance of the joints in bringing pipe to line as is the case where the pipe sections are forced into place. There is also no trouble with bell breakage.

It is important that belt packing be *warm when installed* and not cold and stiff. In the warm summer months it should not be necessary to heat the belts, but in cold weather belts should be heated to 85° or 90° Fahr. to make them flexible and readily worked. This is easily done by dipping in a hot water bath. The nature of the material is such that heat is retained for a considerable period.

When desired, alternate joints can be made up on the bank before lowering into the trench. In this case the entire joint is tightly calked so as to allow ready handling of the two pipe sections with a simple supporting device.

Installation in Wet Trenches:

Servicised Premoulded Belt Packing can be used under very adverse conditions, such as in wet trenches and even under water. When working in wet trenches the bell and spigot of each joint should be painted with Servicised Quick Drying Asphalt Primer when pipe is clean and dry, and before lowering into trench. This ensures a perfect bond between the joint material with the pipe glaze.

PREMOULDED CALKED SEWER JOINTS SPECIFICATIONS

1. Composition

The sewer pipe joint material shall be Servicised Premoulded Sewer Pipe Belt, consisting of a pure petroleum asphalt into which has been incorporated a fibrous filler in sufficient quantity to prevent flow in warm weather and brittleness in cold weather. The material shall have a consistency which will permit its being calked into place with a suitable calking tool, or if desired, which will permit placing by means of pressure applied to the entering pipe section.

The cross-section of the filler shall be wedge shaped to facilitate installation and to aid in obtaining a tight joint. The belts may be furnished in sections, and the combined length of the sections shall equal the average circumference of the annular space between the bell and the spigot, according to A. S. T. M. specifications.

2. Installation

The premoulded filler may be placed by the following methods:

In dry trenches or under ordinary conditions, the bottom portion of the filler shall be placed in the bottom of bell of the pipe which will bring the subsequently placed spigot slightly above the flow line of the pipe. The remainder of the filler shall then be entered into the bell and calked until tight.

Wet Trench Installation

When joints are placed in a wet trench the bell and the spigot surfaces coming into contact with the premoulded filler shall first be painted with Servicised Quick Drying Asphalt Primer before lowering into the trench.

The temperature of the joint filler shall not be below 75° F. at the time of calking or placing.

PRICE LIST SERVICISED PREMOULDED SEWER PIPE BELT

List Prices and Weight per 100 Joints, F. O. B. Factory, Chicago

Inside Diameter	Sections to Joint	Length per Section	Width	Thickness (wedge shape)	Shipping Weight	List Price*
4"	1	17½"	1¾"	3/16" to ½"	41 lbs.	$ 4.45
6"	1	24¾"	2⅛"	3/16" to ½"	78 lbs.	8.50
8"	1	32⅜"	2¼"	¼" to ⅝"	128 lbs.	14.05
10"	2	19¾"	2½"	5/16" to ⅞"	214 lbs.	23.50
12"	2	23¼"	2½"	5/16" to ⅞"	251 lbs.	27.55
15"	2	28¾"	2½"	5/16" to ⅞"	312 lbs.	34.35
18"	3	22⅞"	3 "	⅜" to ⅞"	515 lbs.	56.50
21"	3	26⅞"	3 "	½" to 1 "	747 lbs.	82.15
24"	3	30⅜"	3 "	½" to 1 "	846 lbs.	93.00
27"	3	34½"	3¾"	9/16" to 1¼"	1330 lbs.	146.30
30"	3	38⅛"	3¾"	9/16" to 1¼"	1600 lbs.	175.50
33"	4	31⅛"	4¼"	11/16" to 1⅜"	2220 lbs.	244.50
36"	4	33⅞"	4¼"	11/16" to 1⅜"	2420 lbs.	266.00

Sizes listed above are for standard A.S.T.M. and A.S.M.I. pipe dimensions. When ordering, advise outside dimensions of spigot, depth of bell, and inside diameter at top and bottom of bell; also name the manufacturer of pipe.
*All prices subject to discount. Let us quote them to you.

Q. D. ASPHALT PRIMER

For Laying Sewer Pipe Under Adverse Conditions

Good joints can always be made by the use of Servicised Quick Drying Asphalt Primer in conjunction with Servicised Premoulded Belts.

A bituminous material of brushing consistency which on exposure to the atmosphere sets up into a tough asphaltic mass similar to the belt. It contains light solvents which aids in obtaining good adhesion at the start and evaporates to leave a stiff mastic mass forming a water-tight seal.

In wet trenches, the Primer when placed on the dry bell and spigot of the pipe before the latter is lowered into the trench, repels the water and when the premoulded belt is calked in, forms an immediate bond between the surface of the pipe and the belt.

Its use does not interfere with the placing operations, since it can be applied on top of the trench and the small cost for additional labor is a very small price to pay for tight joints. *Prices on application.*

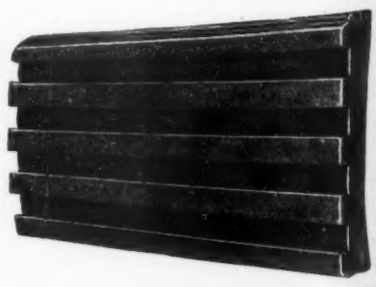
SPECIAL INFORMATION ON PREMOULDED SEWER PIPE BELT

Servicised Sewer Pipe Belt is warranted to make satisfactory sewer joints when used according to directions, with pipe which conforms to dimensional standards published by the American Society for Testing Materials and approved by the American Society for Municipal Improvement.

No responsibility is assumed by the manufacturer for the failure of Servicised Premoulded Sewer Pipe Belt to fit sewer pipe not conforming to those standard dimensions, with their limits of allowance for unavoidable variations in manufacture; nor where pipe with irregular contour is used, or culls.

SEWER, TUNNEL AND EMBANKMENT LINER

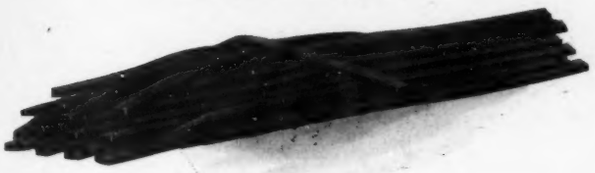
For Thoroughly Waterproofing Concrete Sewers, Retaining Walls, Bulkheads and Tunnels.



Fabricated with grooves so that when placed in the form and the mix poured the slabs become thoroughly keyed to the concrete when it sets. Fire cracks in the structure will not rupture the waterproofing. Impervious to the action of brine, corrosive fumes and gases as well as most acids. Easily handled, light, unbreakable, and can be laid by any ordinary labor under any sort of condition. As liners for Concrete Sewer Pipe they protect the cement and reinforcing steel from deterioration forming a tough, acid and alkali proof as well as resilient inner layer.

BITUPACK

Calking Material in Place of Jute for Hot Poured Joints



Bitupack.—A rectangular stranded asphalt-fibre composition in which the fibre is completely saturated and coated with a high grade petroleum-asphalt. It has a higher degree of efficiency; lower in cost and is easier to handle than jute or any similar packing.

The object of any packing used in connection with hot poured compound is to center the pipe and prevent leakage of the liquid compound into the pipe. Bitupack has sufficient body to hold the pipe rigidly centered and is also plastic enough to fill all irregularities and thus effectively seal the joint. When the hot compound comes into contact with Bitupack both surfaces flux immediately, and the two materials become inseparable when cool. Since Bitupack contains a softer asphalt than the compound, the heat from the latter will also cause a slight fusion at the surface in contact with the pipe, resulting in a perfectly sealed joint.

Calking Bitupack.

The sealing, waterproofing and lasting quality strongly recommends it for use on Sewer Pipe, Sidewalks, Bridges, Viaducts, etc. Standard Strands are ⅜″x¾″ and ½″x1″ in thickness—other sizes furnished on request.

TUFFLEX

The New Ready-to-Use Bituminous Plastic for Sewer Joints

Applying Tufflex Plastic to Ledge of Bell.

Plastic cold trowelling compound composed of asphalt and inert fibrous materials. It has a high degree of adhesion and is easily trowelled into the bell of the sewer pipe. Tufflex is premixed at the factory and furnished on the job ready for use. Various competitive brands are on the market which are furnished the contractors in units to be mixed on the job. The fact that Tufflex is a premixed product assures the engineers of obtaining a proper uniform consistency. Remains flexible indefinitely—is workable in almost any weather—an ideal patching and repair material for concrete as well as sewer pipe.

HOT POURING SEWER PIPE COMPOUND

Asphalt compounds for pouring sewer pipe joints must be of a special nature in order that they will satisfactorily meet the conditions encountered in service. The properties which make bituminous joints superior to cement mortar, namely, weather resistance, flexibility, prevention of root growth and water-tightness, must all be incorporated if a 100% joint is to result. The filler incorporated in the asphalt should be extremely fine so that the composition remains uniform and no appreciable settling takes place. It is added for the purpose of raising the softening point and the specific gravity of the asphalt, thereby increasing flexibility and the resistance to erosion and penetration. We produce two grades of hot pouring compounds known as "Standard Grade" and Type "A."

Standard Grade.—A composition of asphalt and inert materials consisting of approximately 45 to 55% pure petroleum asphalt and fine mineral filler having a melting point of not less than 200° F.

Type "A" Compound.—This product is practically identical with the standard grade except for the fact that it is especially prepared to meet specifications when certain well-known brands are specified. The Type "A" Compound, we are prepared to furnish contractors and distributors to meet any specification.

WEIGHTS AND QUANTITIES OF SEWER PIPE JOINT MATERIALS

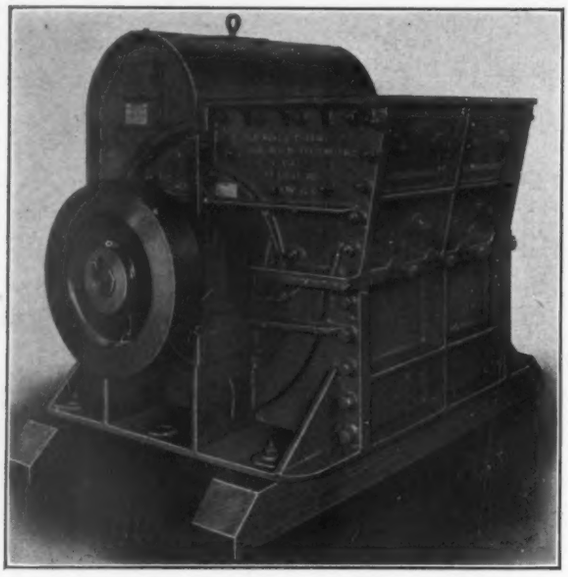
Estimated per 100 Joints of Vitrified Tile Sewer Pipe, A.S.T.M. Dimensions

Inside Diam. of Pipe	Shipping Weight Sewer Pipe Belt	Gallons Q. D. Primer	Weight of Compound Using Jute	Weight of Compound Using Bitupack	Weight of Bitupack	Weight of Tufflex
4″	41 lbs.	½	47 lbs.	47 lbs.	18 lbs.	50 lbs.
6″	78 lbs.	¾	70 lbs.	105 lbs.	27 lbs.	100 lbs.
8″	128 lbs.	1¼	116 lbs.	203 lbs.	44 lbs.	150 lbs.
10″	214 lbs.	1½	140 lbs.	279 lbs.	53 lbs.	225 lbs.
12″	251 lbs.	1¾	169 lbs.	337 lbs.	62 lbs.	300 lbs.
15″	312 lbs.	2⅛	313 lbs.	418 lbs.	80 lbs.	425 lbs.
18″	515 lbs.	3	371 lbs.	621 lbs.	93 lbs.	525 lbs.
21″	747 lbs.	3½	516 lbs.	860 lbs.	132 lbs.	675 lbs.
24″	846 lbs.	4	592 lbs.	986 lbs.	150 lbs.	825 lbs.
27″	1330 lbs.	5¼	777 lbs.	1555 lbs.	194 lbs.	1110 lbs.
30″	1600 lbs.	5¾	985 lbs.	1975 lbs.	251 lbs.	1425 lbs.
33″	2220 lbs.	7¼	1068 lbs.	2490 lbs.	269 lbs.	1700 lbs.
36″	2420 lbs.	7¾	1462 lbs.	3410 lbs.	370 lbs.	2200 lbs.

GRUENDLER CRUSHER & PULVERIZER CO.

Dept. S, 2915 N. Market Street, St. Louis, Mo.

Shredders for Disposal of Sewerage, Sludge, Screenings and Garbage



Type of Garbage Shredder installed by City of Atlanta, Ga.

Gruendler Shredders handle sludge and screenings so that 100% will pass bar screen and eliminate trouble at Ball valve and through system, requiring little or no attention.

Gruendler Garbage Shredders in any capacity for handling rubbish and garbage for incinerators or to be used as fuel in power plant and for disposal through sewerage system.

Fifty years manufacturing well-known Swing Hammer principle to meet any capacity—small or large.

NOVO ENGINE COMPANY

260 Porter St., Lansing, Mich.

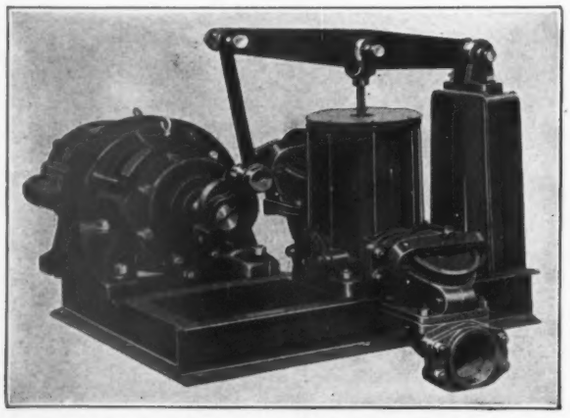


Figure 1759—Novo Single Vertical Sludge Pump. Power 3-HP. Geared Head Motor. Note: Large handhole plates, over valves and adjustable eccentric to change stroke length.

Full floating, circular disc valves. When valve opens, it completely unseats throughout its entire area, giving maximum clearance. **Flushing Plug**—On both discharge and suction. **Capacity**—Per stroke, 1 to 1.4 gallons, dependent on stroke length. Per minute, 47 to 66 gallons. Strokes per minute, 47.

HORIZONTAL ROLLER RING SLUDGE PUMP

Single cylinder, double acting, motor or engine driven, V-belt drive.

Size—5" suction and discharge. **Stroke**—4". **Plunger**—10" in diameter, with ¾" diameter roller rings. **Power Unit**—3-5 HP., 3 phase, 60 cycle, 220, 440 or 550 volt, 1800 R.P.M. motor or 4-5 HP., 1200 R.P.M., single cylinder engine. **Valves**—Large valve area, 21.6 sq. in., allows free and easy passage without agitation. **Capacity**—92 to 145 G.P.M. at 30 to 50 R.P.M. **Displacement per Stroke**—3.08 gallons.

Send for complete descriptive bulletins and prices on these pumps.

NOVO SLUDGE PUMPS

Roller Ring Principle

Novo Sludge Pumps operate on the exclusive roller ring principle. The seal is maintained by two acid and oil resisting rolling rubber rings on the plunger. They are pressed against the cylinder wall and the side of the piston, making an absolutely liquid-tight seal. This does away with plunger packing, diaphragms, etc.

Vertical, Single Cylinder, Single Acting Pump. Roller Ring Sludge Pump

Size—4" suction, and discharge. **Stroke**—Variable, 3" to 4". **Plunger**—10" in diameter, cast iron, grooved for two ¾" diameter roller rings. **Power Unit**—Geared Head Electric Motor, 3 HP., 3 phase, 60 cycle, 220, 440 and 550 volt. **Valves**—

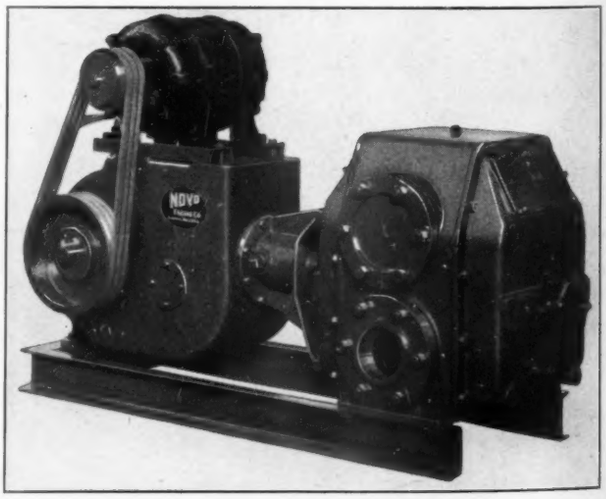


Figure 1729—Novo Horizontal Double Acting Sludge Pump. Note: Large handhole plates at end of pump cylinder. V-belt drive for quiet operation. Flushing plug at top of pump. Drain plug at the bottom.

MENSURATION*

Calculating Areas, Volumes, Surfaces

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

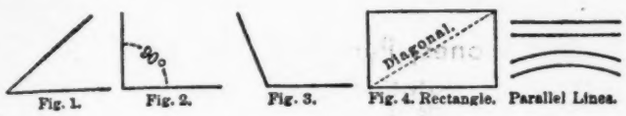


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

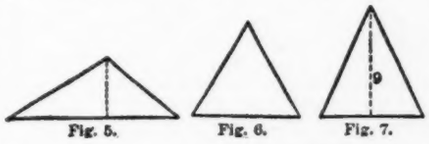


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

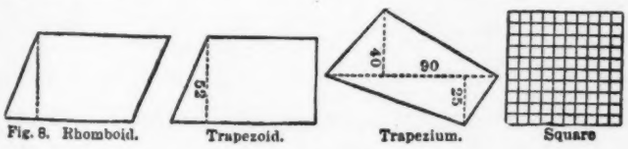


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A trapezoid is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

*Reproduced from "Rapp's Calculator," published by C. Rapp & Sons, Chicago, Ill.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A trapezium is a quadrilateral having none of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A rightangled triangle has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

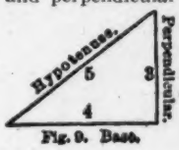


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

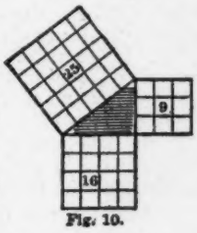


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a tringular field whose hipotenuse is 75 rods, base 60 rods? Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

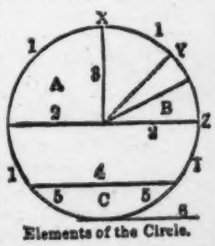
Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square? This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$,
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the circumference of a circle, the

diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\ 1/7 = 88$ in.

To find the diameter of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times 3183 = 46$ in.

To find the area of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the radius of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

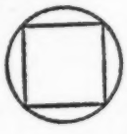
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117\frac{3}{4}$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the area of a sector of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

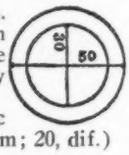
Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

To find the area between the two concentric circles. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.



Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An ellipse is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an eclipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the area of an eclipse. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

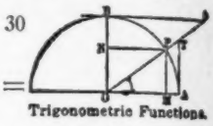
Triangle. Square. Pentagon. Hexagon. Octagon.

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times 433 = 389.7$ in. T; $10^2 \times 4.824 = 482\ 84$ in. O.


Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A_1 versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A cube is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$*12^3 = 1728$.

Find cu. ft. in a cu. mile.

Answer—$5280^3 = 147197952000$.

A parallelopiped is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10\frac{1}{2} \times 3 \times 1\frac{1}{4} = 39\frac{3}{8}$.

A prism is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

$10^2 \times .433 \times 2 = 86.6$ sq. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082\frac{1}{2}$ cu. in.

A globe or sphere is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

A cylinder is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A cone is a solid, which has a circular base and tapers uniformly to a point called vertex.

A pyramid is a solid, resembling a cone, having three or more triangular sides.

Cone. Pyramid.

To find the area of a cone or pyramid. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in, and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78\,54 \times 12\frac{1}{2} \div 3 =$ 32.25 cu. in.

The frustum of a cone or pyramid is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the area of a frustum of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the volume of any frustum. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

3)549(183, area of av. base of F. of sq. pyr.

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq, small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\,7/12$ sq. in., area of average base; $12\,7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\,7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A spheroid or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A cylindrical ring is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness, by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of greatest cube that can be inscribed in a given globe. Rule—Multiply the diameter of the globe by .577.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

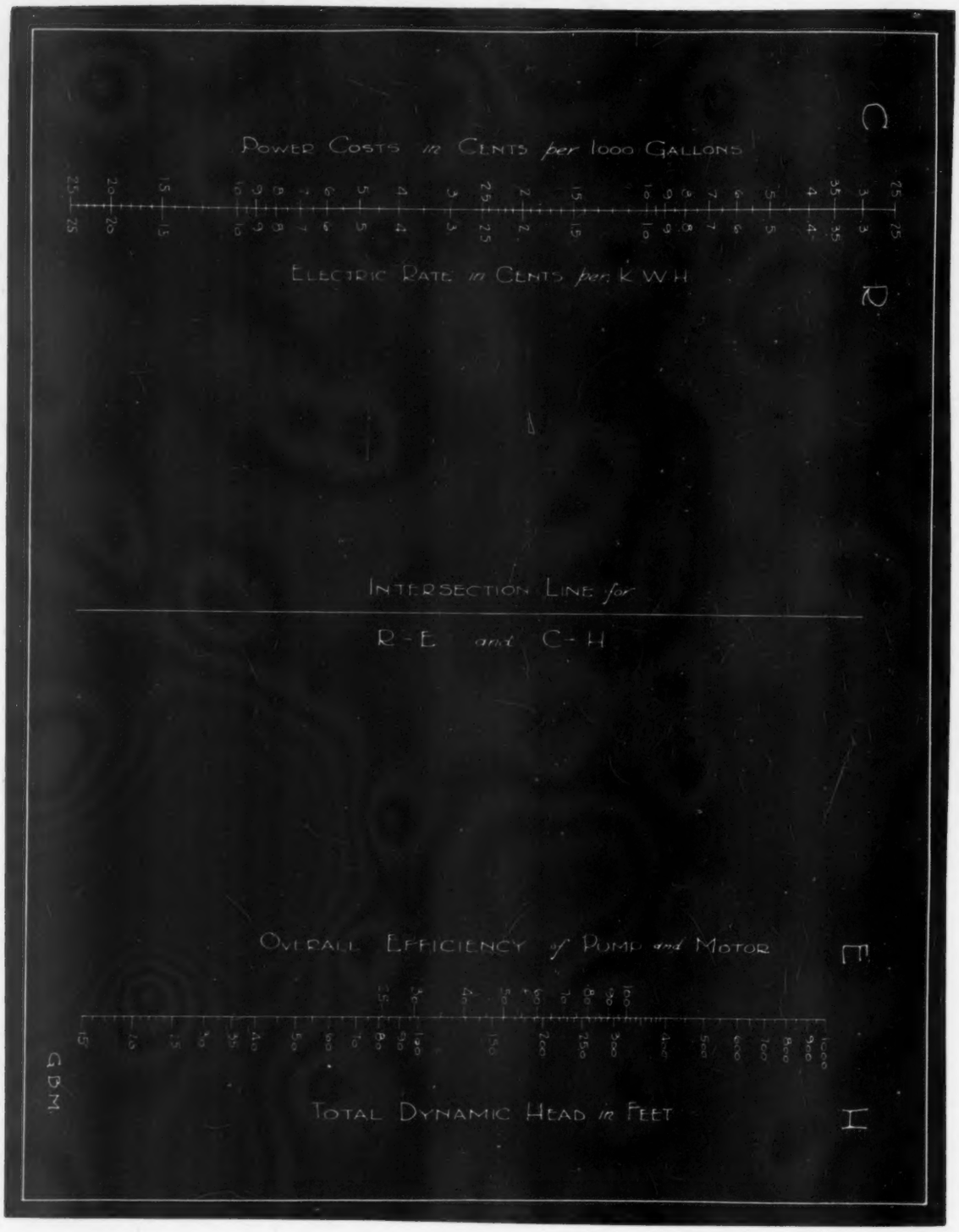
To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

NOMOGRAPHIC CHART REVEALS POWER COSTS IN CENTS PER THOUSAND GALLONS

Contributed by: George B. Massey, Consulting Engr., Chicago, Ill.



In using the above chart to obtain power costs in water pumping, one end of the straight edge is placed at the point on Scale E which represents the overall efficiency of the pump and the motor. The other end of the straight edge is placed at the point on Scale R which represents the electric rate in cents per KWH. With the straight edge in this position, make a small mark on the intersectional line at the point where the straight edge crosses this line.

By revolving the straight edge about the point on the intersection line so that one end of it coincides with the total dynamic head in feet (Scale H) the other end will show on Scale C the power costs in cents per thousand gallons.

As indicated on the intersection line, the Scales R and E are used for one position of the straight edge and Scales C & H for the other position.

AUTOMATIC PRIMER COMPANY

(Valve and Primer Corporation)

113 West Washington Street, Chicago, Ill.

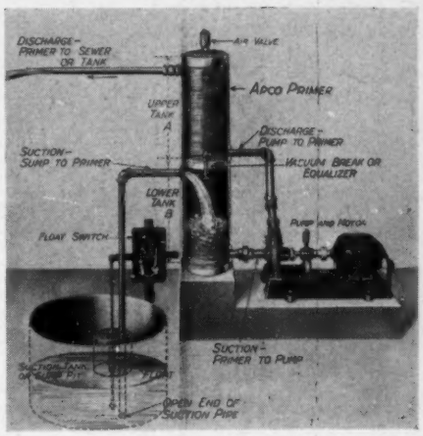
APCO AUTOMATIC PRIMER

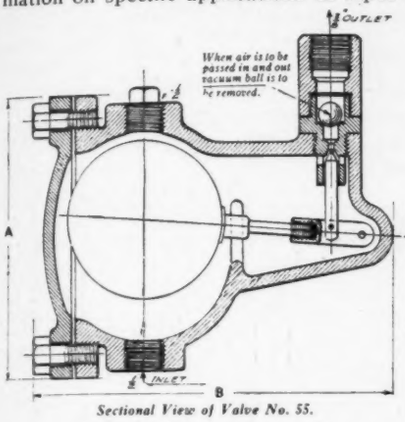
Apco Primer is a simple tank and piping system, without moving parts or anything to get out of order. Its operation is entirely automatic and requires no attention. This is a desirable feature in sump pumping and in water supply systems for towns, estates, and industrial plants. It does not affect the characteristics of the pump to which it is connected. It will operate on suction lines of any length, against any head, and at any capacity, AND WITHOUT FOOT VALVES.

Are used on suction lift, unsubmerged centrifugal pumps for water supply systems, sewage disposal, sump pumping, trench and irrigation work, unloading tanks and tank cars. They are especially valuable on intermittent pumping service.

Apco Primers are made for any desired capacity. Primers can be furnished made of special materials for handling acids and other corrosive liquids. Information on specific applications of Apco Primers will be furnished upon submittal of data. Primers are furnished from stock. Send for price list, sizes, capacities, etc.

This company manufactures a Vacuum Priming System which can be used for any pumping condition.





Sectional View of Valve No. 55.

Apco Valve No. 100

For Pressures up to 150 lbs.

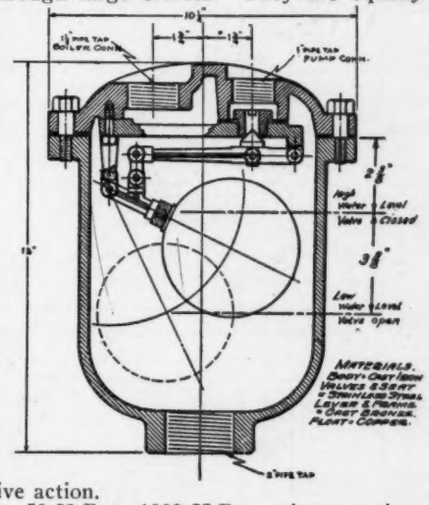
APCO AUTOMATIC AIR VENTING VALVES (Relief and Release)

For the automatic release of air or gas from pipe lines, pumps and various types of tanks. On large pumping systems in which the several pump casings are connected to a vacuum tank, the insertion of an Apco Air Relief Valve between each pump and tank will prevent any liquid being taken over when air is evacuated from the pump and suction lines.

The Apco Air Venting Valves are scientifically constructed, simple and compact, operate continuously without attention and are moderate in price. Apco Valves are made in a variety of sizes and capacities so as to take care of pressures from 10 to 500 pounds.

Compound leverage as developed in Apco No. 200 Series insures the utmost in positive automatic action. Here is rugged, lasting dependable construction, seldom if ever requiring attention.

These APCO Valves effectually solve the problem of all high duty requirements, that is, where it is necessary to work against pressure in excess of the ordinary and to provide for air release through large orifices. They are equally efficient where large venting capacity is required at lower pressures—and in such instances effect great economies in pumping and transmitting equipment. **APCO No. 200 series are ideal on water pumping and distribution of all liquids, including gasoline and oil.**

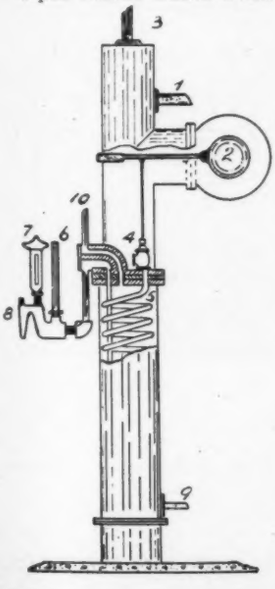

10"
1" PIPE TAP BOILER CONN.
1" PIPE TAP PUMP CONN.
2½"
High Water Level Valve Closed
3½"
Low Water Level Valve Open
MATERIALS. BODY-CAST IRON VALVES & SEAT-STAINLESS STEEL LEVER & FITTINGS-CAST BRONZE. FLOAT-COPPER.
1" PIPE TAP

Apco Valves are guaranteed to give continuous service without further attention after being installed in a size and capacity suited to the conditions. Normally made of bronze or iron, depending upon the size and service, but for special conditions when specified. All valves can be furnished with vacuum balls.

APCO STEAM BOILER FEED PUMP CONTROL AND FEED WATER REGULATOR

A simple device for controlling the operation of a steam boiler feed pump—for single boilers. No stuffing boxes are used, consequently there is no drag on the valve movement, and no trouble from this source.

Apco Steam Boiler Feed Pump Control operates with the change of water level in the boiler and controls pump speed to maintain boiler water line at the most efficient point.



The Pump usually operates continuously at the slowest possible speed to maintain desired water level in boiler—insuring greatest efficiency and safety of operation. The compound lever principle employed in the controller is the most sensitive and efficient movement known and makes for positive and effective action.

Will control steam boiler feed pumps on boilers from 50 H.P. to 1000 H.P. maximum rating, and at pressures up to 500 lbs. per sq. in.

The same general construction is used in our line of Feed Water Regulators.

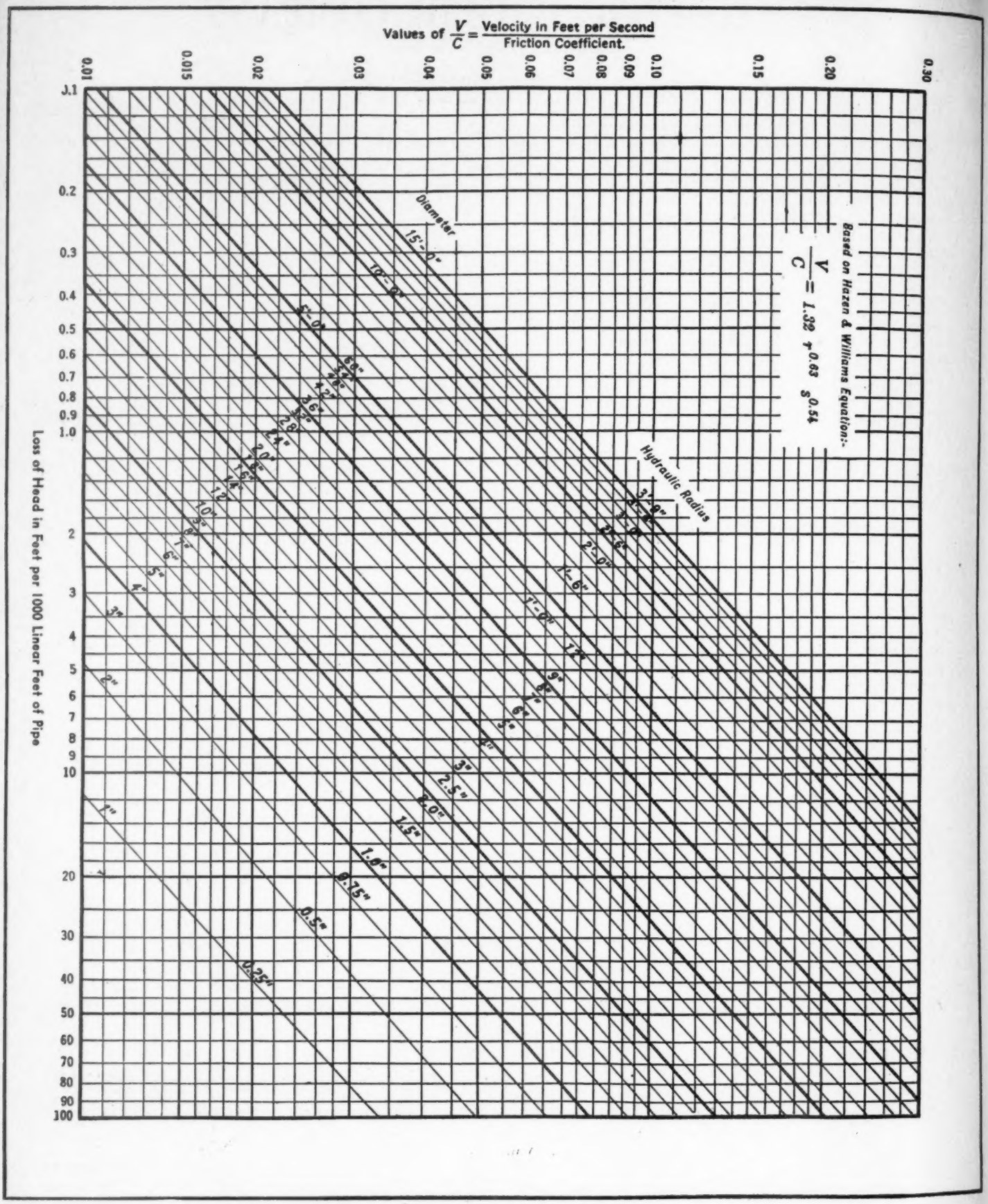
THE MOSINEE CONTINUOUS BOILER BLOW DOWN

***KEY TO ILLUSTRATION.** 1. Connections to Boilers. 2. Regulating Float. 3. Connection for Steam flashed by Boiler Water to Heating System or Heater. 4. Discharge Valve to Heat Exchanger. 5. Heat Exchange Coil. 6. Gauge indicating quantity of Blow Down from Boiler. 7. Thermometer indicating Temperature of Blow Down from Boiler. 8. Discharge to Sewer. 9. Make Up Water Connection to Heater. 10. Hot Water Connection to Heater.*

The Mosinee Boiler Blow Down is a direct outgrowth for the demand for more economic boiler operation. In controlling of boiler water impurities the object is to keep the concentration sufficiently low with minimum blow down and a minimum heat loss. **The Mosinee Boiler Blow Down** accomplishes this purpose by continually blowing down a calculated quantity of water and utilizing the heat of this blow down by flashing a portion of it into steam and preheating of make-up water.

SMALL INVESTMENT—The investment in a **Mosinee Continuous Boiler Blow Down** is usually repaid in fuel savings alone in a few months.

MINIMUM UPKEEP COST—**The Mosinee Continuous Boiler Blow Down** is so constructed that the upkeep is negligible.



Reproduced from Catalog No. 36—Taylor Forge and Pipe Works, Chicago, Ill.
Original source—"Hydro-Electric Handbook"—John Wiley & Sons.

FULLER COMPANY

CATASAUQUA, PA.

Chicago: 1118 Marquette Bldg. **San Francisco: 320-321 Chancery Bldg.**

PRODUCTS:

The Airveyor—for unloading and conveying fine, granular, and crushed materials.

Fuller Rotary Air Compressors and Vacuum Pumps.

Fuller-Kinyon and Fluxo Conveying Systems for conveying dry pulverized materials.

Feeders, Weighing Batchers, Bin Signals, and Bin Gates for pulverized materials.

THE AIRVEYOR

The Airveyor is commonly used for unloading, elevating and conveying fine, granular, and crushed materials from cars and ships, and for reclaiming from bulk storage and stock piles. Hundreds of these systems are now in service, handling a wide variety of bulk materials. Their present uses range from simple unloading systems to those which have solved the problem of distributing materials throughout large industrial plants. They range in capacities and design from small systems for unloading cars and trucks, at a few tons an hour, to the large systems which have cut the unloading time of ocean-going vessels.

There are two types of Airveyors: the "Receiver" type, recommended for granular and crushed materials carrying relatively little dust, such as grains, crushed coal, etc., and the "Filter" type, which handles dusty materials with absolute cleanliness. The Filter type is employed for materials such as soda ash, lime, and silica. Each type may be applied in a wide variety of arrangements to meet specific requirements. For example, a single Airveyor unit may unload cars and withdraw from storage by vacuum, and convey to remote receiving points by closed-circuit vacuum, or closed or open circuit pressure systems. Pressure systems are furnished for conveying from bins or pulverizers to storage and process bins.

Economies and Operating Advantages

The Airveyor offers tangible savings beyond the difference in price between bulk and bag shipments. As compared with other types of conveyors, they offer substantial savings in handling and storage costs. A single unit, operated by one man, can in many cases accomplish all of the unloading, conveying, and distribution required for the plant. Storage facilities may be of the simplest, as the Airveyor will recover from all forms, from open stock-piles to enclosed steel bins.

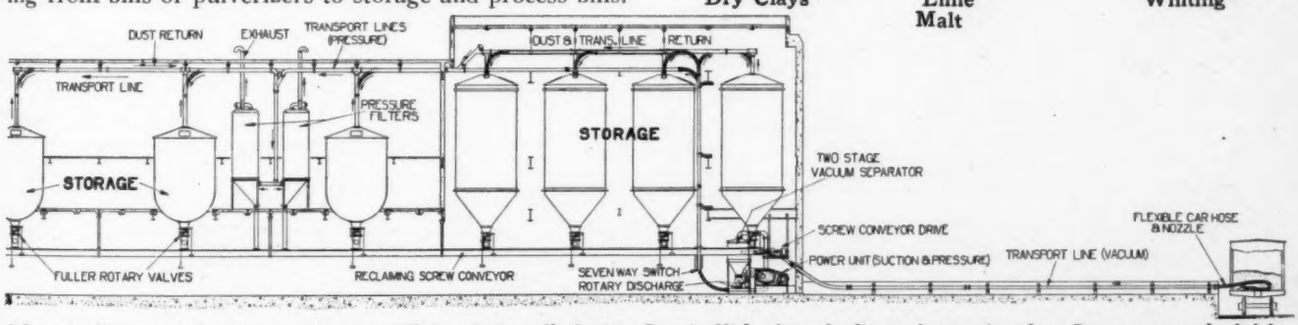
First costs are not excessive. Simple unloading systems compare favorably in price with mechanical conveyors, but when materials have to be handled over relatively long distances or elevations; or must be recovered from storage and distributed to various parts of the plant, Airveyors offer very substantial savings. Obviously the installation cost is much less, as the Airveyor unit is compact, and pipe lines are easily installed and carried on simple supports.

Maintenance requirements are negligible. There are a minimum of moving parts, and these are adequately protected against wear and damage. One of the exclusive features of Airveyor design is the absence of moving parts, which account in part for the fact that these systems have enviable records in long, severe service.

The absolute cleanliness of the system not only eliminates loss of material, but overcomes dust nuisances and hazards. The system is entirely vermin proof.

The Airveyor Conveys:

Alum	Flour	Resins
Arsenic	Fullers Earth	Seeds
Bauxite	Grains	Silica
Crushed Coal	Gypsum	Soda Ash
Dry Clays	Lime	Whiting
	Malt	

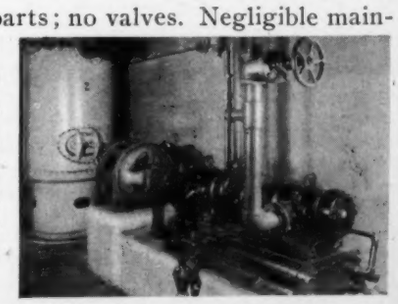


Schematic diagram of the Airveyor System installed at Springwells Station, Detroit, Mich., for unloading and conveying alum. Box cars are unloaded by suction, the material conveyed to the receiver, and from this point by pressure to seven storage bins. The exhaust air from the storage tanks is cleaned by bag filters.

FULLER ROTARY COMPRESSORS AND VACUUM PUMPS

Single and two-stage Compressors and Vacuum Pumps are available in a full range of capacities up to 1800 c.f.m. at standard motor speeds . . . pressures up to 125 lb. gage . . . vacuums up to 99 per cent of barometer.

Among the unique features of these machines are extraordinary capacity with reference to size, weight and floor space requirements. Direct drive at common motor and gas engine speeds without reduction gearing; lack of vibration; air flow free from pulsation; few working parts; no valves. Negligible maintenance requirements with the ability to operate continuously at full load for long periods without mechanical attention. All parts are readily accessible.



Photograph—Fuller Rotary Two-Stage Compressor at Cleveland, Ohio, Incinerator Plant.

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^6	Square feet
" "	1.196×10^6	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^6	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^3	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

INERTOL COMPANY, Incorporated

401 Broadway, New York City

Western Branch: 447 Sutter Street, San Francisco, Cal.

INERTOL PRODUCTS for Better Plant Maintenance

Spalling or rough concrete is hard to keep clean. Rusting equipment causes all kinds of trouble. A well kept plant is more easily run! Inertol Products will save you many hours of work and make your plant clean, sanitary and attractive.

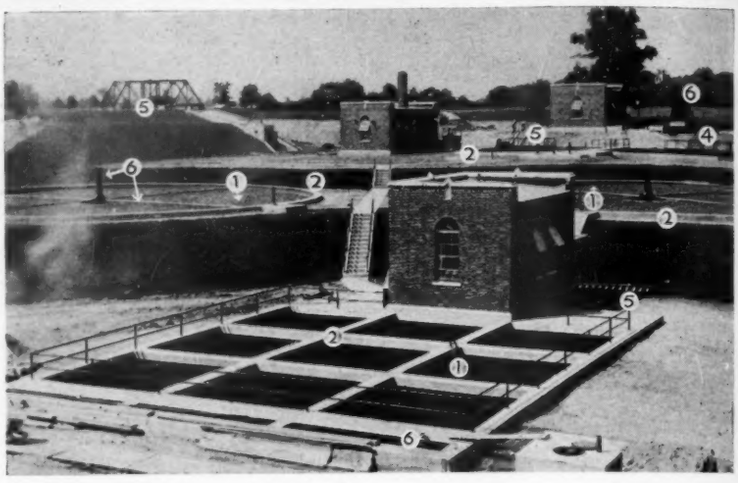
USE INERTOL

1. ON ALL CONCRETE BELOW SEWAGE LEVEL: for "tile surfacing" all concrete in contact with unsettled sewage. Apply INERTOL STANDARD in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

2. ON ALL CONCRETE ABOVE SEWAGE LEVEL: for frostproofing, acidproofing and as a decorative finish, also as a protective coating against chlorine and hydrogen sulphide on floors, walls and ceilings. Apply INERTOL RAMUC ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

3. ON SMOOTH IRON OR STEEL BELOW SEWAGE LEVEL OR IN MOIST ATMOSPHERE for durable protection against sewage and condensation. Apply INERTOL STANDARD in 3 coats, at the rate of 1 gallon for 400 square feet, each coat.

4. ON SHARP EDGED, ROUGH STEEL BELOW SEWAGE LEVEL and for durable protection of thin steel sections, regardless of edges, corners and angles. Apply 2 coats INERTOL STANDARD at the rate of 400 square feet per gallon and 1 coat of INERTOL STANDARD THICK at the rate of 100 square feet per gallon.



5. ON ALL IRON AND STEEL SURFACES ABOVE SEWAGE LEVEL: for durable protection and beautiful appearance of steel surfaces exposed to strong abrasion, sewage mist, sun and gases, indoors and outdoors. Apply INERTOL GLAZOFLEX ENAMELS, as per color chart, in 1 or 2 coats over INERTOL GLAZOFLEX PRIMER, at the rate of 1 gallon for 300 square feet for primer and finish coats.

Inertol

BRAINARD & HATCH

246 Palm Street, Hartford, Conn.

THE METER-MASTER

A Rate Recorder attachable to ANY water meter, single or compound.

The only recorder giving a continuous record. Maximum and minimum flows recorded for six or twenty-four hours.

The record of the meter is not interrupted. No batteries.

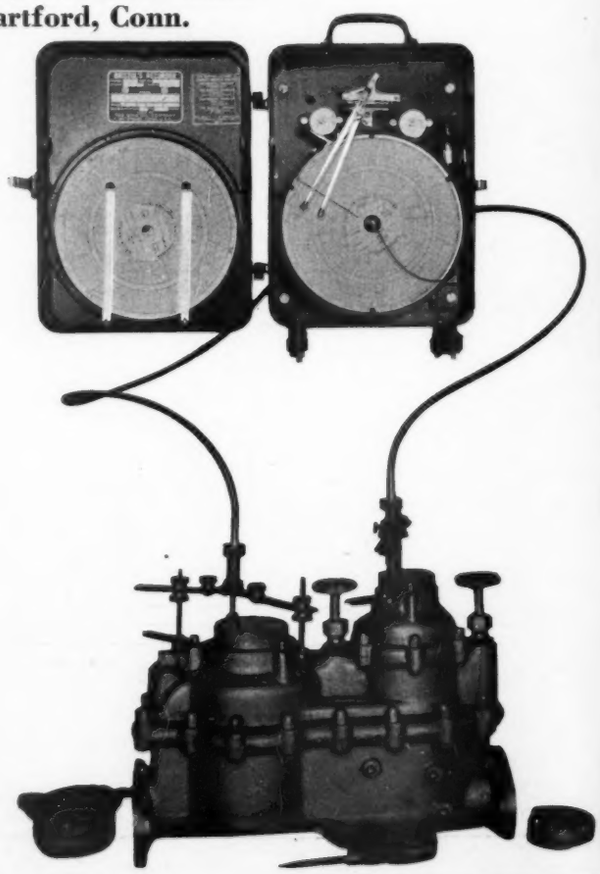
Several users report that it saved its cost in less than two months.

Satisfies customer complaints of high bills.

Saves loss through oversize meters.

It has proved its value to many of the leading water departments. Why not let it do the same for you?

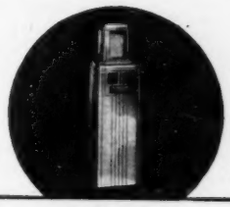
WRITE FOR INFORMATION



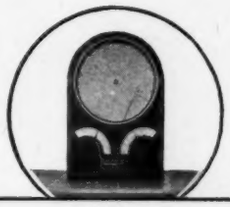
INFILCO

Equipment —
for Every Requirement of Modern Water Purification

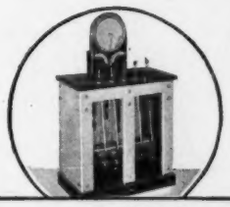
- Acid Feeders and Proportioners
- Activated Carbon Water Purifiers
- Aerators—Nozzle and Tray Types
- Automatic Boiler Blowdown
- Automatic Control Equipment
- Automatic Proportioning Equipment
- Boiler Water Purification Plants
- Chemical Feeders—Dry and Solution Types
- Chemical Proportioners
- Chemical Test Apparatus
- Clarifiers
- Coagulant Feeders
- Color Removal Plants
- Condensate Oil Removal Plants
- Crystalite Water Softeners
- Dechlorinating Plants
- Depth and Water Level Gauges
- Directional Flow Controllers
- Disk Filters
- Electro-Osmose Water Purifiers
- Feed Water Heaters and Purifiers
- Filter Operating and Control Tables
- Filter Strainers and Distributing Nozzles
- Filter Underdrain Systems
- Filtration Plant Equipment
- Flow Indicators and Recorders
- Gravity Filters—Wood, Steel and Concrete Types
- Hot-Flow Water Softeners
- Hydraulic Valve Controls
- Hydrodarco Purifiers
- Iron Removal Plants
- Lime Slakers and Feeders
- Lime-Soda Water Softeners
- Loss of Head Gauges
- Manometers
- Master Controllers
- Milk Filters
- Phosphate Feeders and Proportioners
- Pressure Filters
- Recarbonating Plants
- Rate of Flow Controllers
- Rate of Flow Gauges
- Sampling Tables
- Sewage Meters
- Steam and Gas Purifiers
- Sterilizing Equipment
- Swimming Pool Cleaners, Fittings and Equipment
- Swimming Pool Filtration Systems
- Taste and Odor Removal Plants
- Venturi Tubes and Infilco Meters
- Wagner Bottom Underdrains
- Water Filters for all Requirements
- Water Level Controllers
- Water Softeners of Every Type
- Water Stills
- Zeolite and Zeolite Water Softeners



Robotrol
Infilco Robotrol is a robot filter or softener operator. It backwashes, rewashes (or regenerates) and returns the unit to service — automatically, efficiently and without supervision.

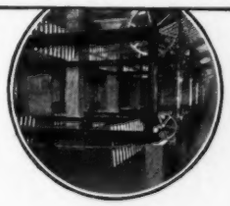


Gauges
Infilco Loss of Head and Rate of Flow Gauges and Infilco Altitude Gauges, Indicating, Recording or Combined Types, for stand or table mounting, are essential to efficient control.

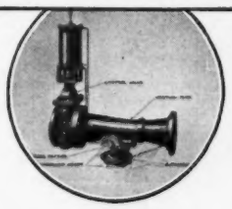


Operating Tables
Infilco Operating Tables with Infilco 4-Way Switches provide finger tip control of hydraulic valve operation; and as a mounting for gauges combine beauty with utility.

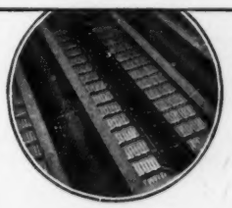
Supermix
Infilco Supermix induces spiral flow, assures intimate contact of water and chemicals, increases floc size, greatly improves the efficiency of sedimentation and effects savings in chemicals.



Rate of Flow Controllers
Infilco Effluent and Wash Water Controllers maintain uniform rates of flow, prevent dangerous wash rates and are noted for their accuracy, low loss of head and reset features.



Underdrain Systems
Infilco Wagner Underdrain provides every essential requirement for perfect wash water distribution — and is equally efficient in the collection of the filtered water.

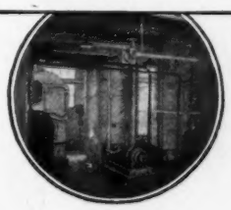


Lime Slakers
Infilco Continuous Lime Slakers combine accurate, dustless feeding of quick lime, efficient slaking and delivery of a uniform milk of lime mixture.

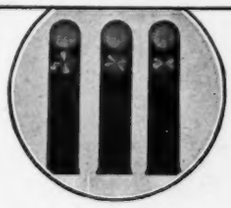
Dry Chemical Feeders
Infilco Dry Chemical Feeders cleanly measure alum, lime, aluminate, carbon, etc. Accurate, efficient and rugged. Manual control or automatic proportioning types.

Aerators
Infilco Aerators — Induction, Cascade, Coke Tray and Spray Nozzle Types — assist in removal of iron and manganese, carbon dioxide, hydrogen sulfide and other odors.

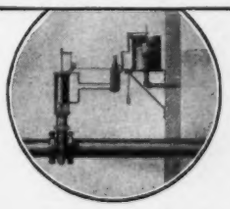
Recarbonators
Infilco Recarbonators — coke, gas or oil fired — provide washed, purified CO_2 to stabilize lime treated water. Infilco Distributors assure efficient contact of CO_2 and water.



Venturi Tubes and Meters
Infilco Indicating, Recording and Totalizing Meters for low and high service pumping and wash water. Infilco Venturi Tubes for metering, chemical proportioning and flow control.

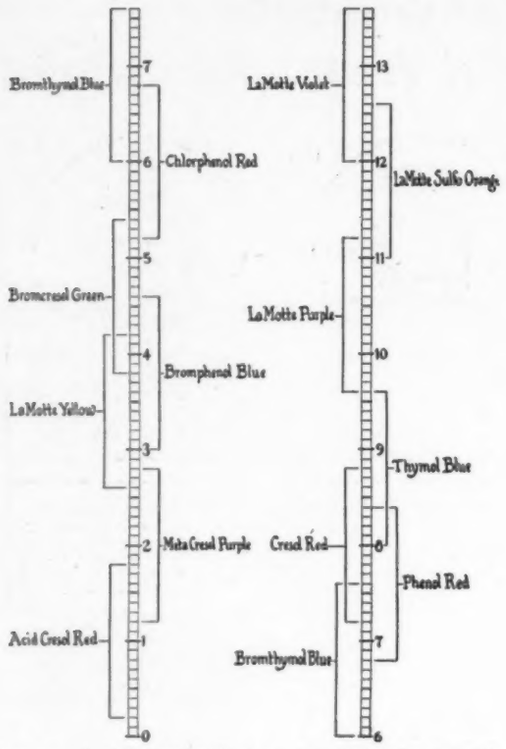


Water Level Controllers
Infilco Water Level Controllers automatically operate hydraulically controlled valves to prevent basins and tanks from overflowing and to maintain levels within definite limits.

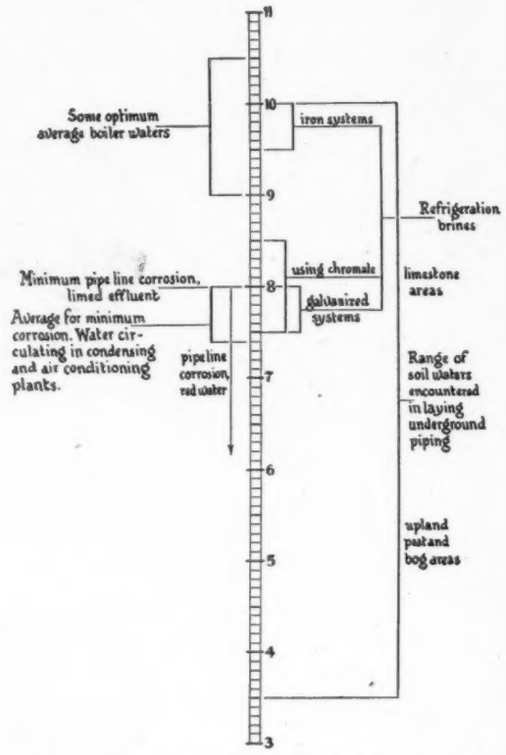


INTERNATIONAL FILTER CO.
Water Purification, Hydraulic Control and Chemical Feed Equipment
59 East Van Buren Street, Chicago, Ill.

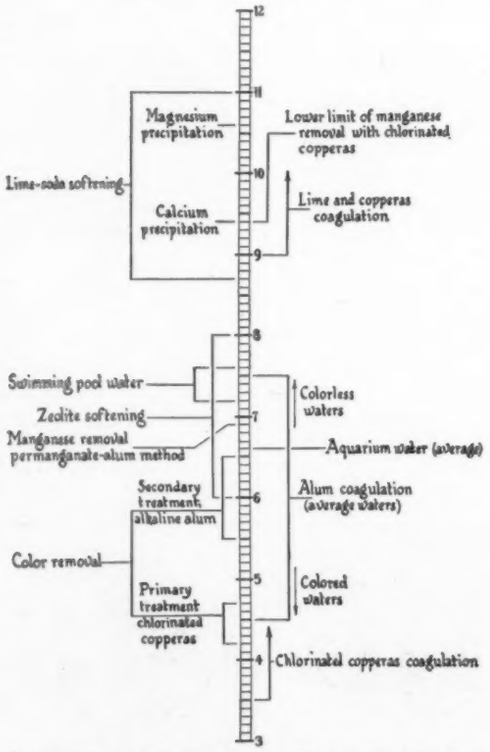
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



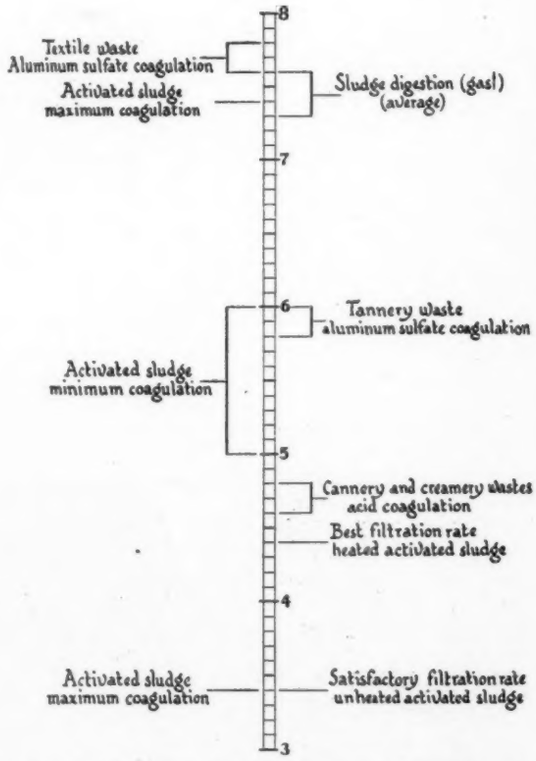
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
using chromate
limestone areas
galvanized systems
Minimum pipe line corrosion, limed effluent
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

PENNSYLVANIA SALT MANUFACTURING CO.

Incorporated 1850

EXECUTIVE OFFICES: 1000 Widener Building, Philadelphia, Penna.

BRANCH SALES OFFICES: New York Chicago St. Louis Pittsburgh Tacoma Wyandotte

---

Our Company takes pride in offering quality products, prompt shipments, and technical service to chemical consumers in the Water Purification and Sewage Treatment Fields.

FERRIC CHLORIDE

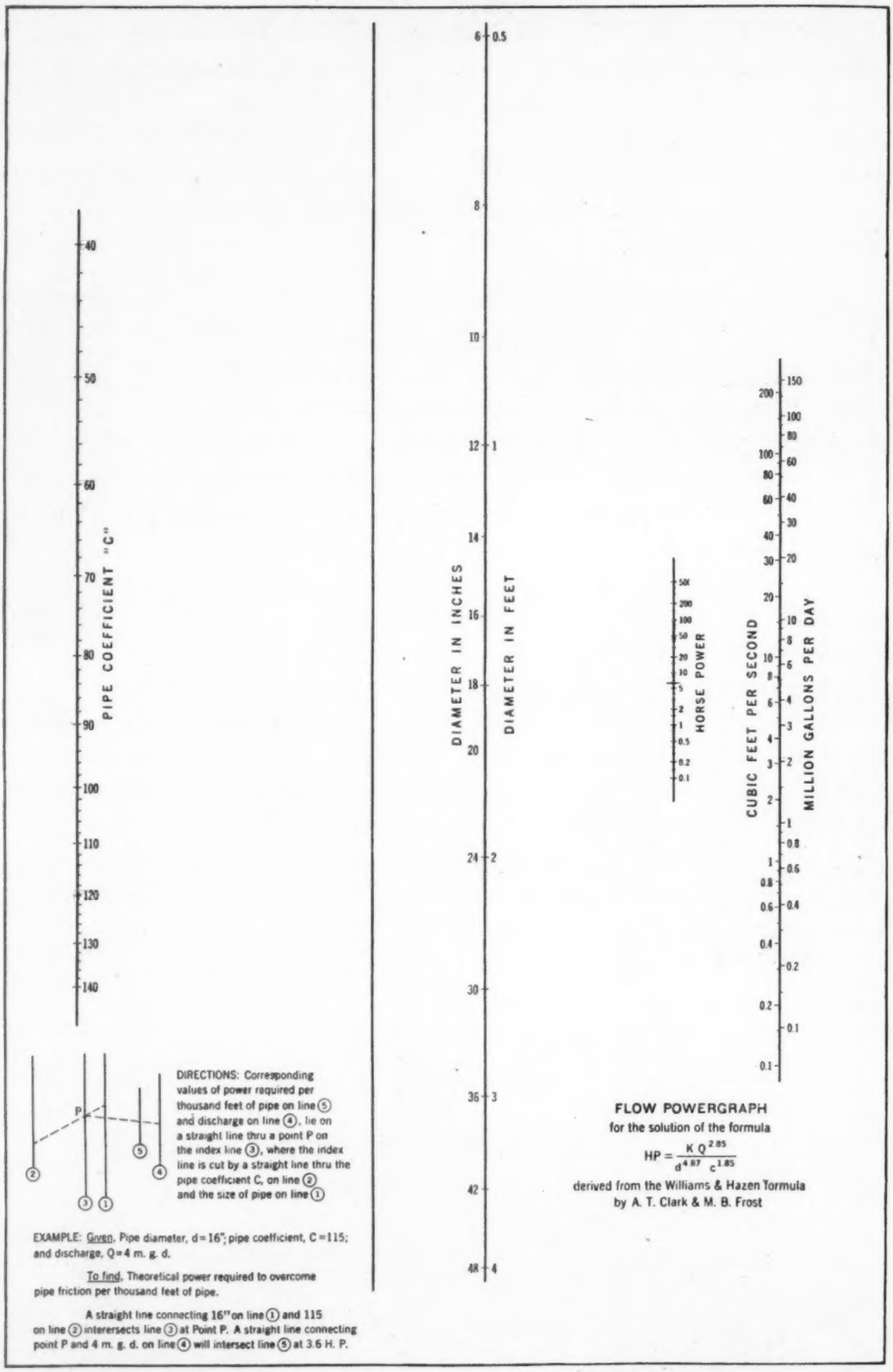
Ferric chloride is a relatively new coagulant but it has been tried, proven, and accepted as the best sludge conditioner for vacuum filtration. It is most effective as a coagulant for the chemical precipitation of sewage and the coagulation of water. Existing plants as well as new installations can be equipped to utilize ferric chloride without involved changes or costly alterations.

Pennsylvania Salt Manufacturing Company are the pioneer producers of ferric chloride and supply either the liquid or anhydrous material.

Anhydrous ferric chloride, containing approximately 98% $FeCl_3$, is packed in 150 pound non-returnable steel drums. It is in powder form, quickly soluble in water, and does not harden, melt, or deteriorate in storage. It is recommended for plants without railroad siding facilities. Minimum carloads are 36,000 pounds but any quantity over 150 pounds can be shipped.

Liquid ferric chloride, containing 39% to 45% $FeCl_3$, is shipped in 4,000 and 8,000 gallon rubber-lined tank cars. Liquid is easily transferred from cars to storage tanks by siphoning, pumping, or applying air pressure to the cars. Liquid ferric chloride is recommended for large consumers with tank storage and railroad siding facilities.

Flow Powergraph



DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①

EXAMPLE: Given, Pipe diameter, d = 16"; pipe coefficient, C = 115; and discharge, Q = 4 m. g. d.

To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.

A straight line connecting 16" on line ① and 115 on line ② intererssects line ③ at Point P. A straight line connecting point P and 4 m. g. d. on line ④ will intersect line ⑤ at 3.6 H. P.

FLOW POWERGRAPH

for the solution of the formula

$$HP = \frac{K\,Q^{2.85}}{d^{4.87}\,c^{1.85}}$$

derived from the Williams & Hazen Formula

by A. T. Clark & M. B. Frost

Devised by A. T. Clark and M. B. Frost of the Community Service Water Company for use in determining the theoretical power required to overcome pipe friction per 1,000 *ft. of pipe*

PHIPPS & BIRD, INC.

Laboratory Apparatus and Chemicals

915 East Carey Street RICHMOND, VA.

PHIPPS & BIRD LABORATORY MIXER

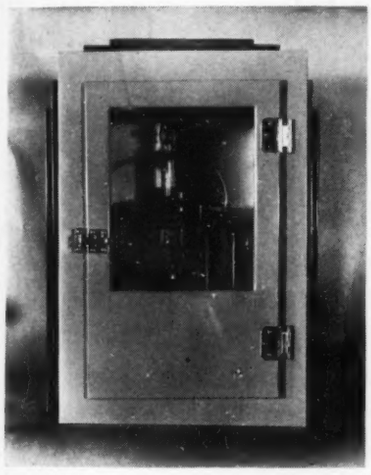
The Phipps & Bird Mixer is designed for alum floc formation determination in treated water. The speed of the paddles may be varied from 15 r.p.m. to 110 r.p.m.

These are the standard units:

Three unit size
Four unit size
Five unit size
Six unit size

SOLUTION FEEDER

This Solution Feeder which is designed on the principle of the operation of a syphon mounted on a parallel motion hinge and supported by a float may be used in small, large or experimental plants in which it is desired to feed any kind of a solution into a system at a constant and continuous rate. A number of these machines are being used to chlorinate small water supplies and swimming pools. Others are being used to feed ferric chloride solution, ammonium sulphate solution, sulphuric acid and other chemicals that are soluble in water.

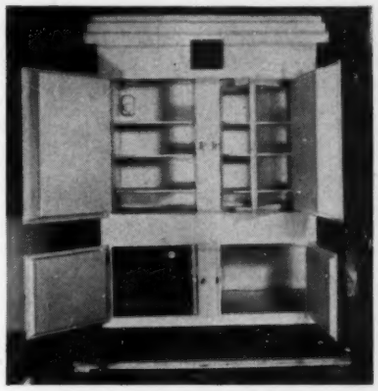


BALDWIN ALUMINA SET

With the Baldwin Alumina Outfit the residual alum in filtered water can be determined accurately and quickly. The accompanying cut shows the complete apparatus including reagents, color standards and neat, hardwood portable carrying case. This case is very important as it protects all apparatus from possible contamination with alum dust.

COMBINED TWENTY DEGREE INCUBATOR AND REFRIGERATOR

The Allied Twenty Degree Incubator and Refrigerator consists of two insulated chambers. In the left hand chamber a temperature as low as five degrees Centigrade (forty degrees Fahrenheit) may be maintained. In the right hand chamber, a temperature of twenty degrees plus or minus one degree Centigrade is maintained. One of the chambers in the lower part houses the refrigerating unit and the other may be used for storage purposes. This is used extensively for B. O. D. determinations.



	Cabinet Size		
	Depth	Width	Height
Refrigerator	17½"	18"	28"
Incubator	15½"	16"	26"
Exterior	26½"	51½"	71"

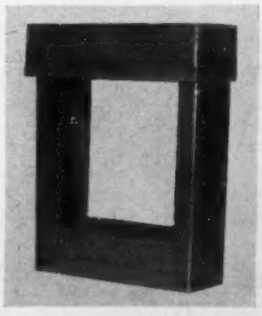
The Refrigerator may be operated independently of the Incubator.

SOLUTION FEEDER WITH PUMP

This is the Phipps & Bird Solution Feeder with pump and was designed for use where the pressure is greater than atmospheric. The pump is so built that it handles the metered output of the feeder. It therefore does not have to be adjusted accurately. All that is required of it is that it handle the entire output of the feeder. The pump has been so designed as to eliminate rubber diaphragm and pistons made of non-corrosive material.

FERMENTATION TUBE SUPPORT

Fermentation tube support of copper for use with fermentation tubes of the Durham or inverted vial form in the Bacteriological examination of water. A layer of cotton is placed in the lid and in this way the plugging of each separate tube is avoided. The tube can be filled with bouillon without handling each tube separately. It is also easy to note whether or not gas has been formed at the expiration of twenty-four or forty-eight hours. The rack holds twelve tubes.



Conversion Chart—pH, Alkalinity, Carbon Dioxide

NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. (This chart was supplied by T. M. Riddick of Nicholas S. Hill, Jr., Cons. Engrs.—Ed.)*

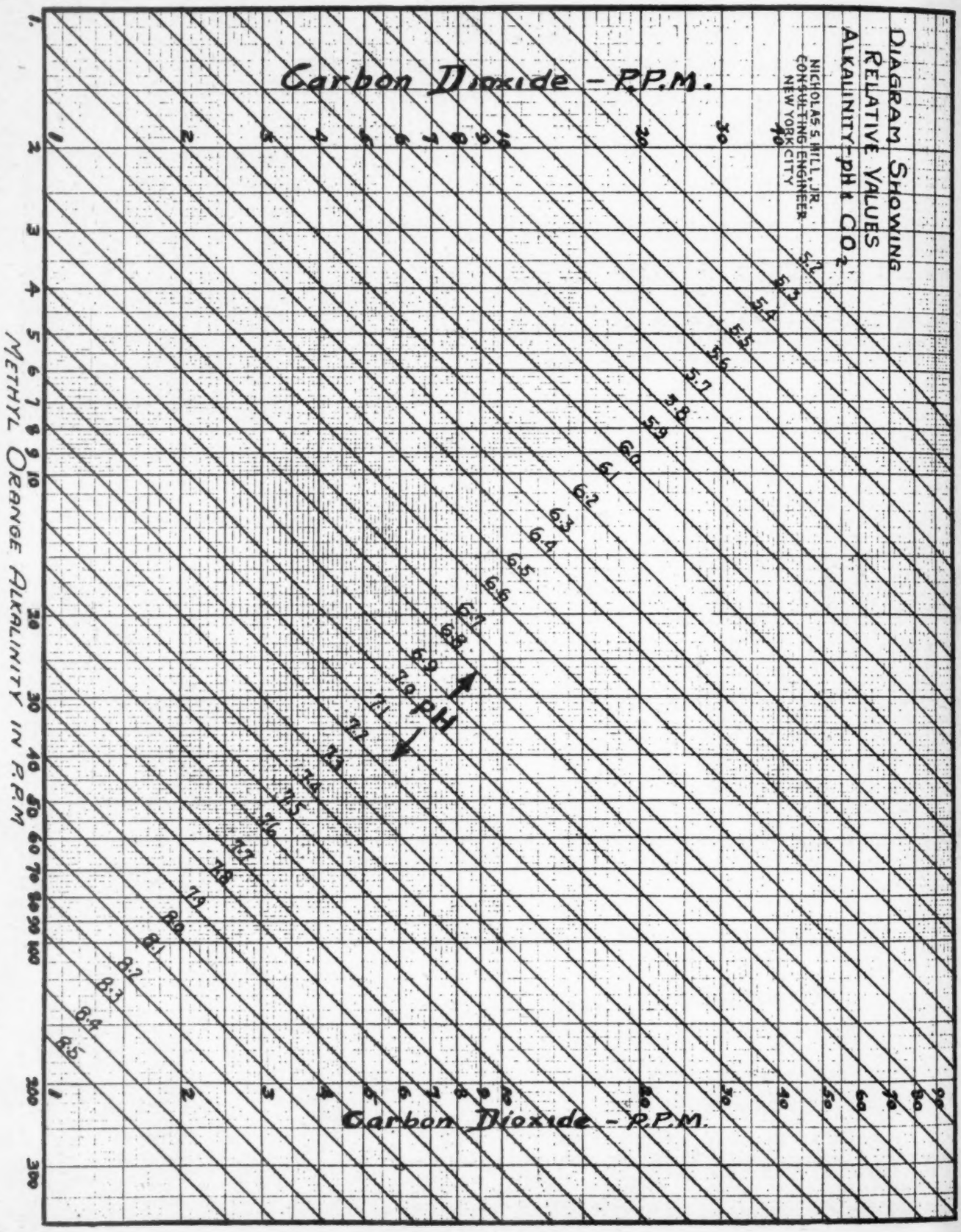


Diagram Showing Relative Values Alkalinity-pH & CO_2
Nicholas S. Hill, Jr. Consulting Engineer New York City
Carbon Dioxide - P.P.M.
Methyl Orange Alkalinity in P.P.M.
Carbon Dioxide - P.P.M.
pH

SYNTRON COMPANY

402 No. Lexington Ave., Pittsburgh, Penna.

SYNTRON

Vibra-Flow

DRY CHEMICAL FEEDERS

Flow dry chemicals by vibration —just like water.

Remote, electrical volume control.

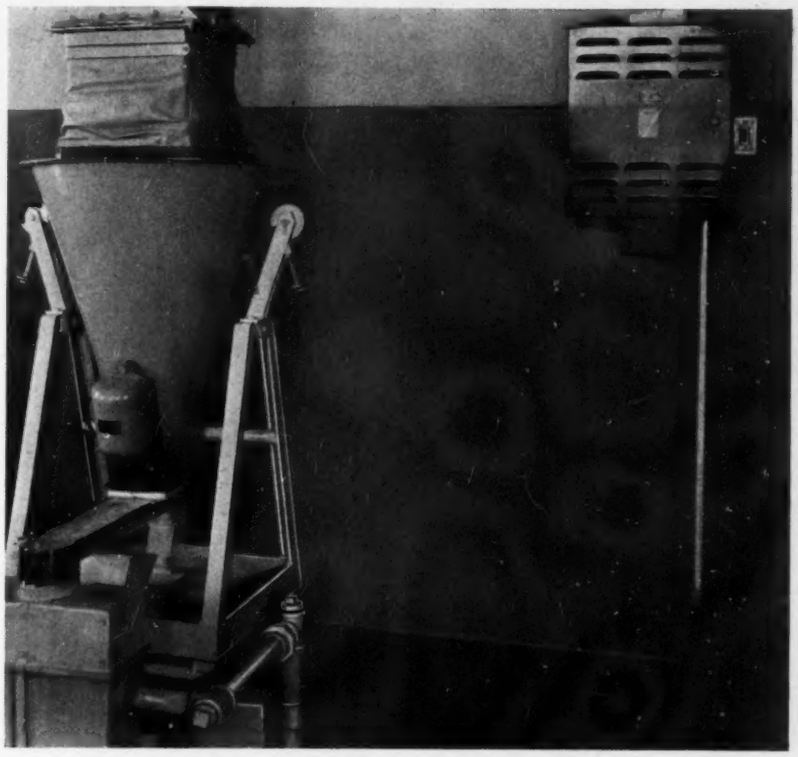
No motors, gears, cams, bearings or other wearing parts.

Also available in—

GRAVIMETRIC TYPE

With recording and indicating scale control.

The latest development in Dry Feeder Equipment



Typical Installation—Showing Seals Against Dust

• IN WATER AND SEWAGE TREATMENT •

CONTROLLED INTIMATE AERATION—MIXING CONTROLLED INTIMATE

★★★ A SIX POINT METHOD ★★★

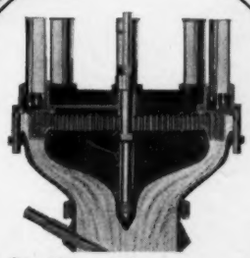
INVOLVING

DIFFUSION — COMPRESSION — RETENTION
EXPULSION — SURFACE CONTACT — AGGLOMERATION

Capacities of Aer-o-mix installations now aggregate more than ¼ billion gallons per 24 hours.

Aer-o-mix is made in a type and capacity to fit every existing or contemplated plant. Gravity—Rotary—Pneumatic—Pressure.

Write for illustrated folder



"Impg Suction"
AERO-MIX
AERATOR - MIXER

IN WATER PLANTS

- Raw Water Aeration
- Quick Chemical Mixing
- Coagulant Mixing
- Contact Mixing
- Recarbonation
- Filtered Water Aeration

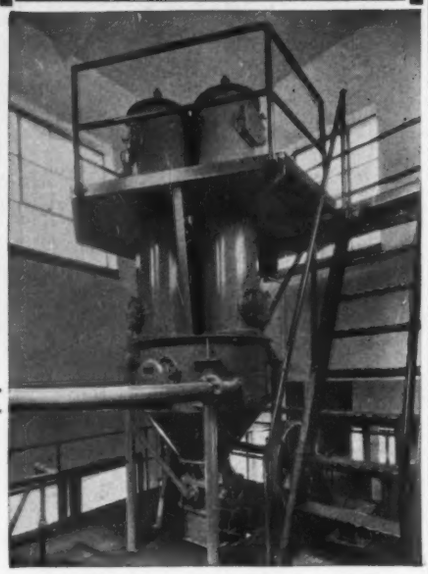
IN SEWAGE PLANTS

- Activated Sludge Aeration
- Trickling Filter Auxiliary
- Mixing For Chemical Precipitation

VOGT MFG. CO.
INCORPORATED

FACTORY MAIL ADDRESS
P. O. BOX 1122
LOUISVILLE, KY.

find out how DRACCO PNEUMATIC CONVEYORS REDUCE HANDLING COSTS



Station Receiving

There are innumerable ways that soda ash, alum, lime and ferrous sulphate may be handled more efficiently and economically by DRACCO Pneumatic Conveyors. We have reduced labor costs and saved floor space. DRACCO Pneumatic Conveyors have reduced costs in so many ways that nearly any Water Filtration Plant could use to advantage.

DRACCO Pneumatic Conveyors
Are Installed in the Following Plants:

Fridley Filtration Plant.....Minneapolis, Minn.
Dalecarlia Filtration Plant.....Washington, D. C.
Municipal Water Softening Plant.....Sandusky, Ohio
Municipal Water Softening Plant.....Ames, Iowa
Lemieux Island Filtration Plant.....Ottawa, Ontario, Canada
Mahoning Valley Sanitary District.....Niles, Ohio
Municipal Water Plant.....Columbus, Ohio
Municipal Water Plant.....Peru, Illinois
U. S. Govt. Filtration Plant.....Fort Leavenworth, Kansas
Municipal Water Plant.....Dallas, Texas
Municipal Water Plant.....Hamilton, Ohio
Municipal Water Plant....Richmond, Va.
Municipal Water Plant..Springfield, Illinois

CONSULT OUR ENGINEERS

For over 20 years our Engineers have concentrated on solving Conveyor problems for Chemical Plants, large and small. Some of the finest plants in the country have used DRACCO Pneumatic Conveyors for years with a big savings of dollars and cents. You are invited to write and obtain the benefit of our years of experience.

For Further Information Write

DRACCO CORPORATION
Successors to the Dust Recovering & Conveying Co.
4079 E. 116th St. Cleveland, Ohio

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1½-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1½-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

SCULPTURED IN TIN

BY L. L. BALCOM

TO the pioneer railroad builders of the last century goes the credit for opening up rich, new territories in the West. To the pioneer chemical companies of today goes the credit for opening up many rich, new fields of activity for industry. Among these companies is EBG—first to produce Liquid Chlorine in the U. S. A. New frontiers... new pioneers! Yet the old confident spirit of the empire builders lives on. When you need Liquid Chlorine—or experienced counsel regarding its use—turn to EBG, the pioneer—first in the country!

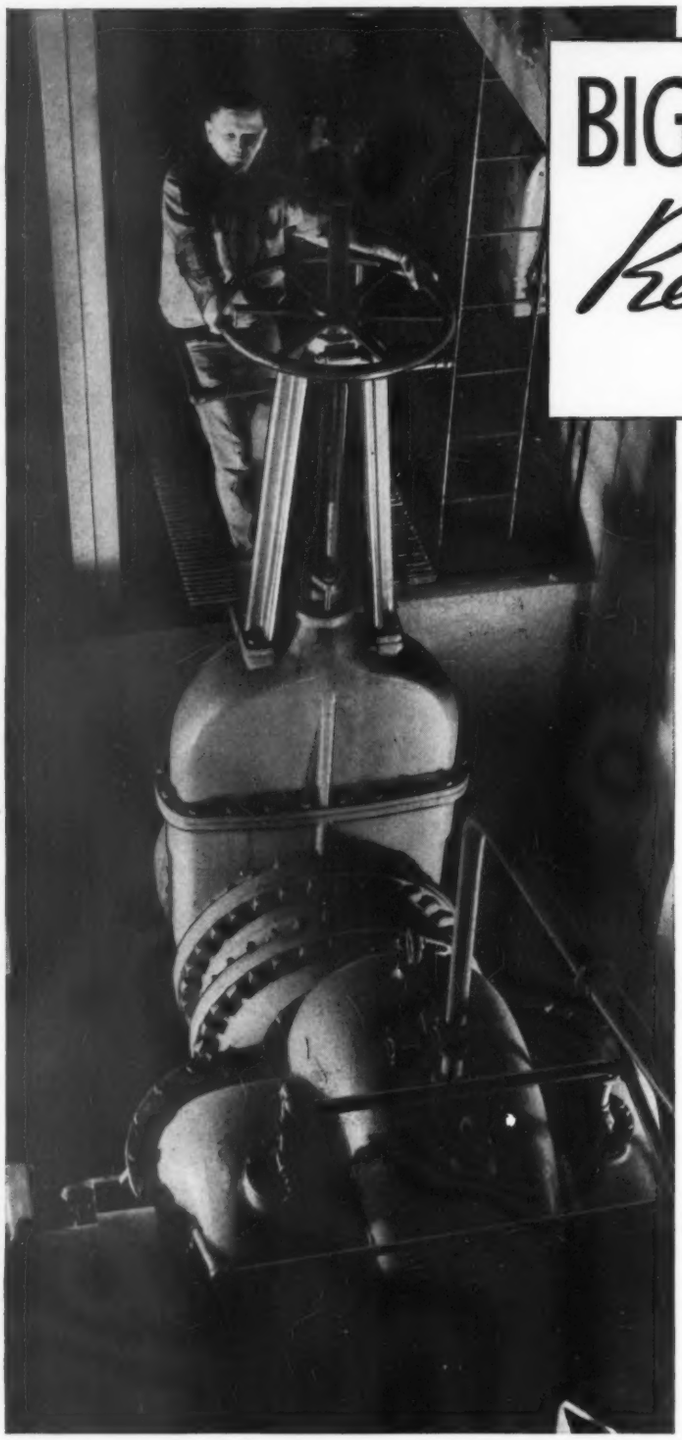
ELECTRO BLEACHING GAS COMPANY

MAIN OFFICE: 9 EAST 41st STREET, NEW YORK, N. Y.

PLANT: NIAGARA FALLS, N. Y.

EBG Liquid Chlorine

FIRST IN THE COUNTRY



BIG *Sizes* MEAN BIG *Responsibilities*

● Men who must shoulder the responsibility of specifying extra large valves dare not guess, seldom can risk experiment. Investments are too large, demands for reliability too imperative.

To their aid Crane brings an abundance of experience and a fund of engineering knowledge built up over three-quarters of a century. Coupled with the outstanding design features of Crane's large valves is a perfected manufacturing technique and the kind of craftsmanship that makes results positive.

Where time is important, the great range of sizes, types, pressure groups and operating mechanisms which Crane is prepared to supply are a decided advantage.

The Crane branch or distributor near you is prepared to give you valuable co-operation and complete information on stock as well as special designs.

When you attend the A. W. W. A. Convention at the Los Angeles Biltmore, June 8 to 12 don't miss the Crane exhibit on display there.

● *Crane 36-inch, O. S. & Y. low-pressure gate valve on centrifugal water pump. Disc accurately guided to its seat, minimizing wear of faces. May be fitted with spur or bevel gearing, or with cylinder for hydraulic operation or with motor drive.*

CRANE

CRANE CO., GENERAL OFFICES: 836 S. MICHIGAN AVE., CHICAGO, ILLINOIS · NEW YORK: 23 W. 44TH STREET

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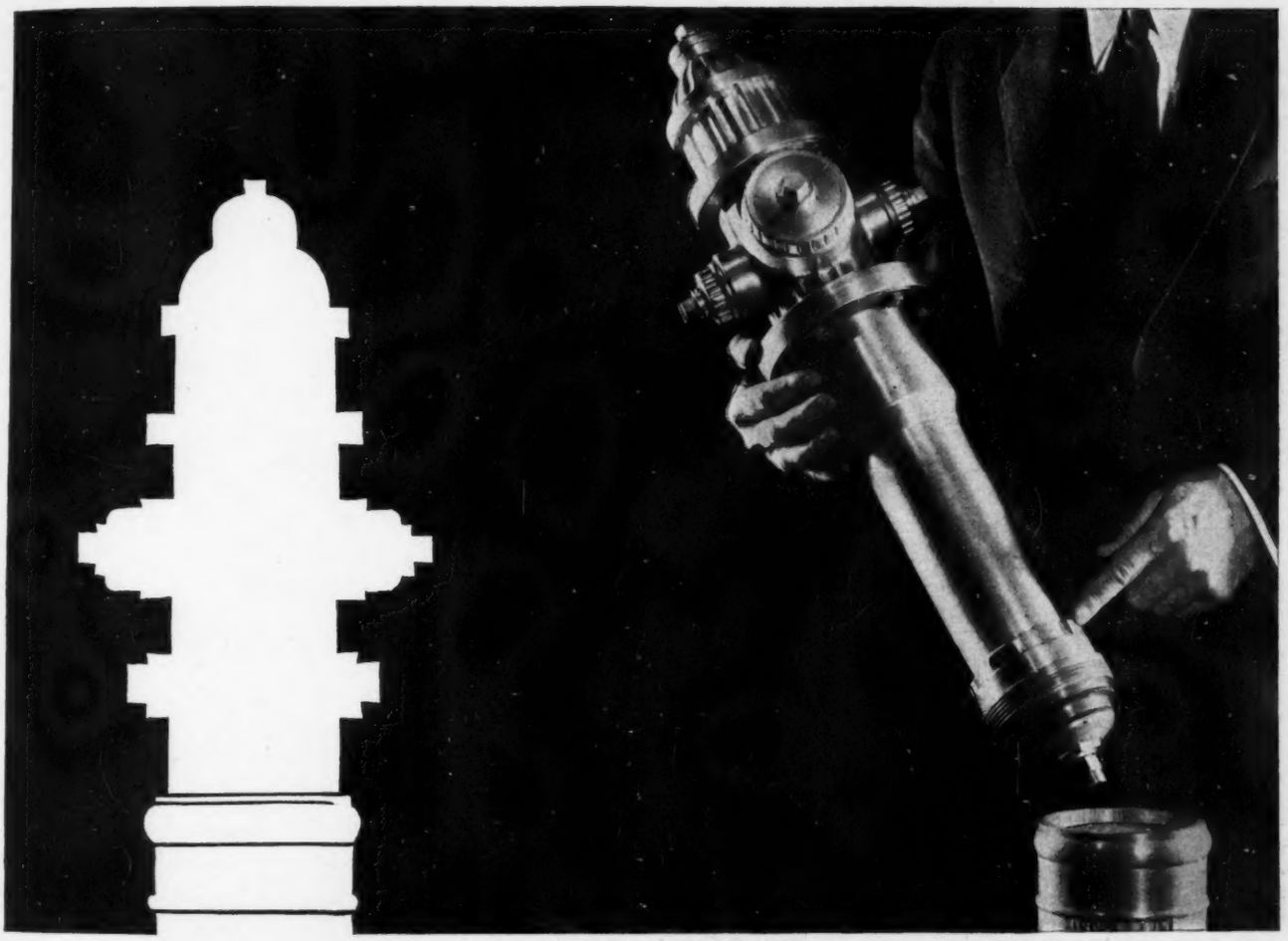
VALVES, FITTINGS, FABRICATED PIPE, PUMPS, HEATING AND PLUMBING MATERIAL

IN *15 Minutes* YOU CAN *Renew* MATHEWS HYDRANTS

This barrel contains all working parts. It is interchangeable with every Mathews Hydrant ever made of the same diameter and trench depth. It is inserted without digging a spoonful of earth or breaking an inch of pavement. Whether Mathews Hydrants are 60 years old and in need of modernizing or 6 months old and broken by traffic, you can renew them in 15 minutes and save excessive installation costs.



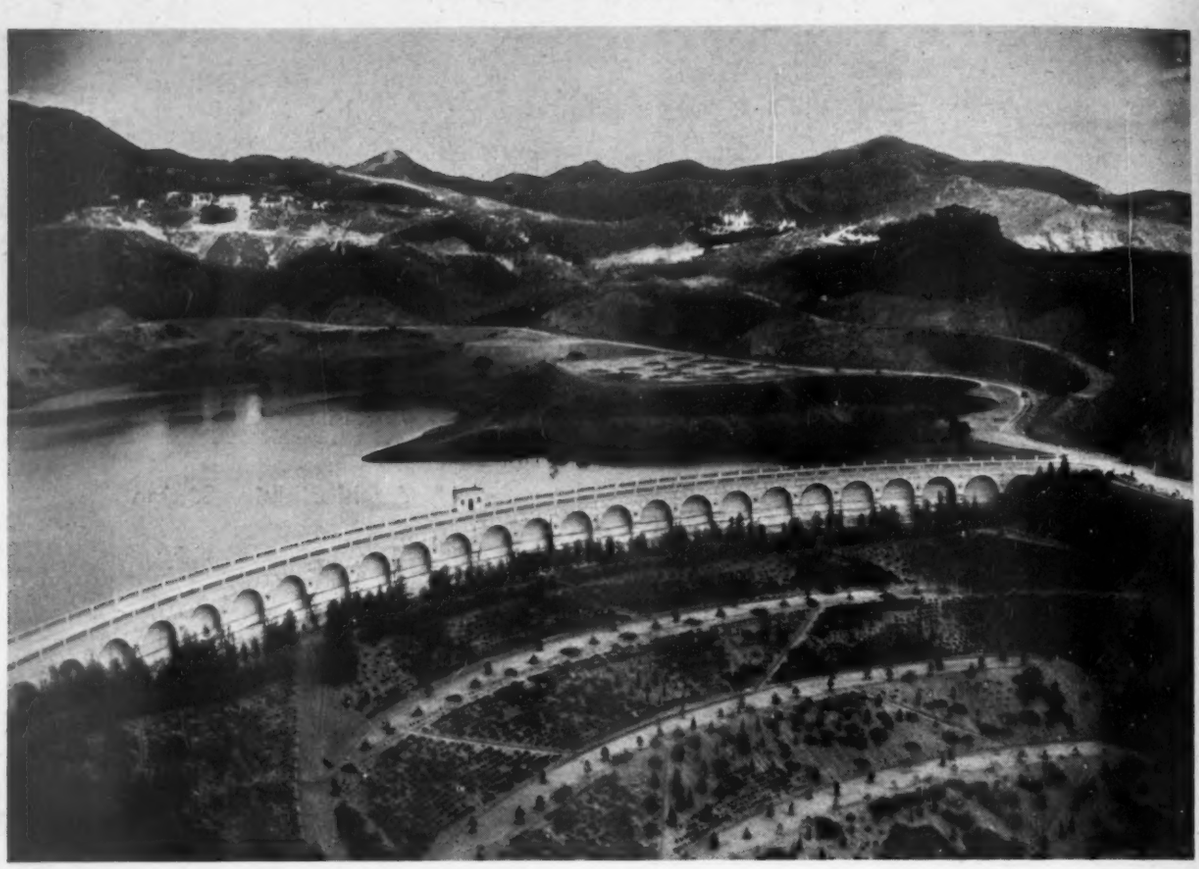
See pages 124 and 125 of this issue

FOR FULL DESCRIPTION, COST, OR MODEL-DEMONSTRATION, WRITE

R. D. WOOD CO. 400 CHESTNUT STREET PHILADELPHIA EST. 1803

Makers of SAND-SPUN PIPE, the lighter, stronger pipe, centrifugally cast in sand molds

Water Works and Sewerage—May, 1936

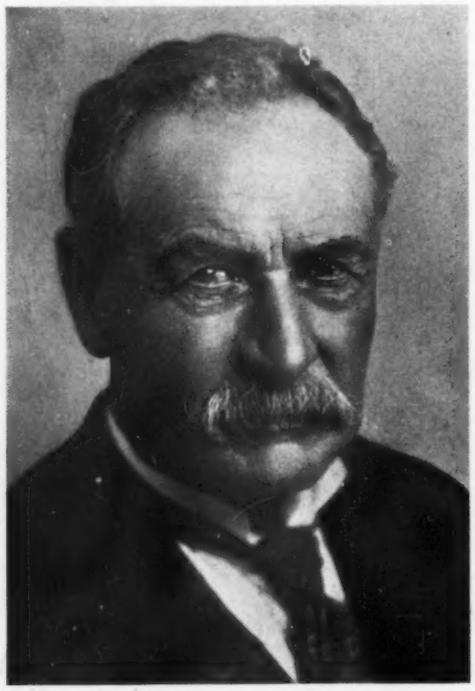


A Dam in a Famed Spot, Named for a Famous Water Engineer

Mulholland Dam, showing new landscaping of earth-fill placed in front of the concrete structure that overlooks Hollywood, and provides closein storage facilities. This dam, a beautiful piece of construction, was later backed with the earth-fill in order to allay fears of America's Movie Colony as to its safety

H. A. Van Norman

Chief Engineer and General Manager of the Water Bureau, was Assistant Chief during construction of the Aqueduct. (President, California Section A.W.W.A.)

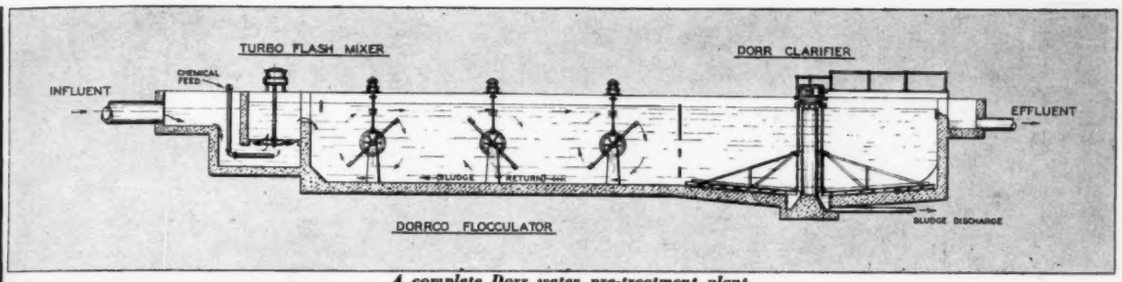


The Late William Mulholland

He rose from a Ditch Tender to Chief Engineer and Builder of Los Angeles' Aqueduct System

William W. Hurlbut

Engineer of Water Works, Los Angeles. (President-elect of A.W.W.A.)

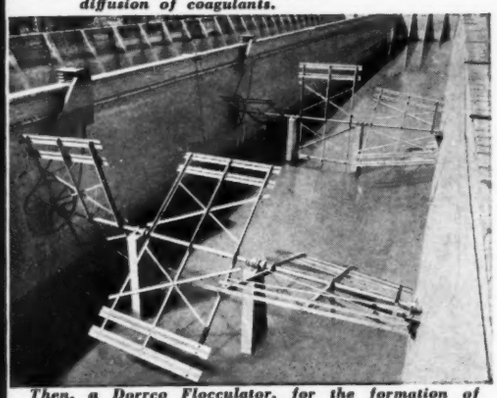


A complete Dorr water pre-treatment plant

First, a Dorrco Flash Mixer for the diffusion of coagulants.

SAVE

20-30 PERCENT OF COAGULATION COST



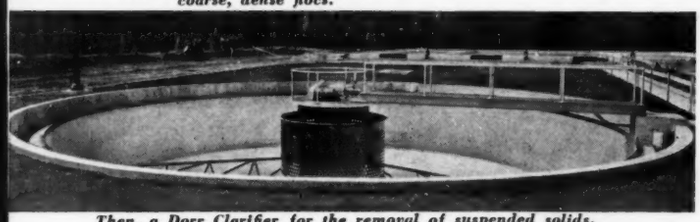
Then, a Dorrco Flocculator, for the formation of coarse, dense flocs.

These three Dorr steps—taken in sequence—will pay for themselves out of chemical savings. They will give you an easier water to settle and filter—a better final water to drink.

Below are three cases from practice as reported in the technical press.

[redacted]—Richmond, Va.

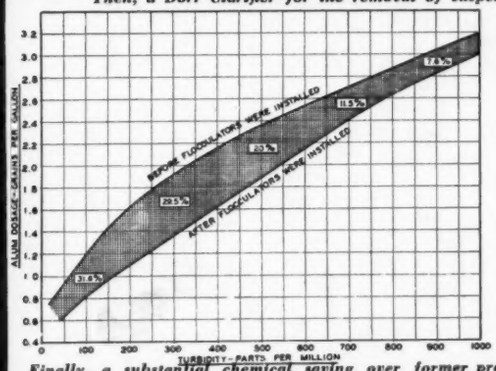
Installed cost $18,000
Chemical saving.....1.8 grains per gal.
Annual chemical saving.....$23,000



Then, a Dorr Clarifier for the removal of suspended solids.

[redacted]—Louisville, Ky.

Installed cost.....$11,000
Chemical saving.....20-30%
Annual chemical saving.. $5,000
Also:
40% longer filter runs
30% less filter wash



Finally, a substantial chemical saving over former practice.

[redacted]—Old Hickory, Tenn.

Conditions—
Flash Mixing..... 4 min.
Flocculation .....40 min.
Sedimentation .....65 min.
Power Consumption.....9 KWH per M. G.
Chemical Saving.....23.5% (see chart)

Let a Dorr engineer figure the savings possible under your own conditions.

THE DORR COMPANY INC.

CHICAGO TORONTO • **ENGINEERS • 247 Park Ave., New York** • DENVER LOS ANGELES

DORR TECHNICAL SERVICES AND EQUIPMENT ARE AVAILABLE FROM THE FOLLOWING COMPANIES:

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FRANCE: Soc. Dorr-Oliver, Paris
ENGLAND: Dorr-Oliver Company Ltd., London
AUSTRALIA: Crossle & Duffy Pty. Ltd., Melbourne
SOUTH AFRICA: Edward L. Bateman Pty. Ltd., Johannesburg
GERMANY: Dorr Gesellschaft, m. b. H. Berlin
JAPAN: Andrews & George Co. Inc., Tokio

Just Around the Corner IN LOS ANGELES

OLD SPANISH MISSIONS and HOLLYWOOD CAFES, sunny beaches and snow-capped mountains, orange groves and desert sands—all just around the corner in Southern California, combining to make your trip to the A.W.W.A. Convention an experience you'll long remember.

And just around the corner, [illegible] you'll find a W&T Chlorinator giving th[illegible] able service you've learned to expect at home. 44 Visible Vacuum Chlorinators [illegible] thirds of them fully au[illegible] operation—in daily service, sterilize the wate[illegible] 14 Divisions of the Los [illegible]—while 67 other W&T equipments give complete satisfaction on swimm[illegible] ge disposal plants and allied sanitary installations in Los Angeles today.

Look over the W&T equipment on display at the Convention, then step "just around the corner" to a nearby installation and hear another testimonial to the accuracy and dependability of W&T equipment, an[illegible] dorsement of W&T service.

This year come to the Convention, [illegible] the scenic beauties of Southern California, renew old friendships and acquire new [illegible]. And don't forget the new types of W&T equipment in Booths 1, 2, 3 and 4. Let us welcome you there.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, NEW JERSEY Branches in Principal Cities. Main Factory Belleville, N.J.

"The Only Safe Water Is a Sterilized Water"

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